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REVISION 4

NAVAL SHIPS' TECHNICAL MANUAL

CHAPTER 300

ELECTRIC PLANT - GENERAL

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CHAPTER 300

ELECTRIC PLANT - GENERAL

SECTION 1.

SOURCES OF INFORMATION

300-1.1 SCOPE

300-1.1.1 GENERAL. Almost every function involved in the operation of a naval ship depends upon electric power for its accomplishment. Electric power trains and elevates the gun and missile mounts, turns the rudder, runs auxiliary machinery, and in electric drive ships, drives the propulsion motors. Electricity operates the interior communication and combat systems, energizes the radar, sonar and navigation equipment, and, through the radio, provides communication with other ships, aircraft and the shore. Owing to the extensive and highly diversified use made of electric power, the electric plant on a naval ship necessarily comprises many different items of equipment for electric power generation, distribution, and utilization. Detailed instructions for the operation of specific types of equipment will be found in other chapters of this manual. This chapter is concerned primarily with certain features common to all types of electrical equipment, namely, sources of information on electrical equipment, electrical safety precautions, electrical insulation and insulation resistance, and maintenance and reconditioning of electrical equipment.

300-1.2 SOURCES OF INFORMATION

Information on the electric plant in each ship is obtainable from a study of the plant itself and the following sources:

a. Chapters of this manual
b. Volume 3 of the **Ship Information Book** entitled **Power and Lighting Systems**
c. Technical manuals and pamphlets
d. Drawings
e. Damage Control Book
f. Planned Maintenance System.

300-1.2.1 CHAPTERS IN THE NAVAL SHIPS' TECHNICAL MANUAL. The following chapters in the Naval Ships' Technical Manual (NSTM) should be consulted for information on equipment and procedures used in the generation and distribution of electric power, and its use in special applications, and equipment repair procedures:

NSTM Chapter 079, Volume 3, Damage Control-Engineering Casualty Control

NSTM Chapter 223, Submarine Storage Batteries

NSTM Chapter 235, Electric Propulsion Installations

NSTM Chapter 244, Propulsion Bearings and Seals

NSTM Chapter 302, Electric Motors and Controllers

NSTM Chapter 310, Electric Power Generators and Conversion Equipment

NSTM Chapter 313, Portable Storage and Dry Batteries

NSTM Chapter 320, Electric Power Distribution Systems

NSTM Chapter 330, Lighting

NSTM Chapter 400, Electronics

NSTM Chapter 422, Navigation and Signal Lights

NSTM Chapter 430, Interior Communication Installations

NSTM Chapter 475, Magnetic Silencing

NSTM Chapter 491, Electrical Measuring and Test Instruments

NSTM Chapter 555, Shipboard Firefighting

NSTM Chapter 631, Preservation of Ships in Service - Volume 2, Surface Preparation and Painting

NSTM Chapter 670, Stowage, Handling, and Disposal of Hazardous General Use Consumables

NSTM Chapter 9880, Damage Control, Compartment Testing and Inspection

300-1.2.1.1 Additional Information. Additional information on the electrical installation is to be found in other chapters dealing with equipment in which electric power is used.

300-1.2.2 SHIP INFORMATION BOOK. New ship specifications require that the contractor furnish copies of the Ship Information Book to each ship built in accordance with those specifications. The Ship Information Book consists of several volumes, with titles as shown below:

Volume 1. Hull and Hull Mechanical Systems

Volume 2. Machinery Plant

Part 1. Propulsion Plant, General Design, and Operating Procedures

Part 2. Auxiliary Machinery, Piping, Air Conditioning, Ventilation, and Heating Systems

Volume 3. Power and Lighting Systems

Part 1. General Description and Design Information of Systems

Part 2. General Description of Electrically Operated Auxiliaries

Volume 4. Electronic Systems

Volume 5. Interior Communication Systems

Part 1. Interior Communication Systems

Part 2. Sound-powered Telephone Systems, Voice Tubes, and Message Passing Facilities

Volume 6. Weapons Control Systems

Volume 7. Ballasting Systems, As Applicable

Volume 3 serves a particular ship and consists of two parts:

Part 1. General Description and Design Information of Systems.

Part 2. General Description of Electric Equipment and Electrically Operated Auxiliaries.

300-1.2.3 TECHNICAL MANUALS. Technical manuals are furnished for the more important items of electrical equipment and systems installed aboard ship. These technical manuals contain a general description and instructions covering installation, operation, care and maintenance, and safety precautions. The technical manual for a particular piece of equipment furnishes more detailed information than is to be found in the other chapters of this manual or in Volume 3 of the Ship Information Book and should be consulted freely in order to obtain a complete understanding of the equipment.

300-1.2.4 DRAWINGS. Each ship is provided with drawings showing the salient features of the electrical installation in general and of individual items of the installation in detail.

300-1.2.5 DAMAGE CONTROL BOOK. Many naval ships have been supplied with electrical wiring diagrams for the ship's Damage Control Book. The number and type of diagrams vary for the different ships and may include electrical wiring diagrams for the main drainage pumps, steering gear, main and secondary batteries, lights, antiaircraft defense, electronic equipment, and bus ties. Other diagrams show the location of the permanently installed fittings and cable of the casualty power system, and of the portable switches and racks for the storage of portable cable. The Damage Control Book should be consulted for information on the use of the casualty power systems. Refer also to **NSTM Chapter 079, Damage Control.**

300-1.2.6 PLANNED MAINTENANCE SYSTEM (PMS). PMS was developed to provide each ship, department, and supervisor with the means to effectively plan, schedule, and control shipboard maintenance. When installed, the PMS supersedes any existing preventive maintenance programs and conflicting technical directives for equipments covered. Equipments not covered are to be maintained in accordance with existing procedures. The PMS is fully described in OPNAVINST 4790.4, **Ships Maintenance and Material Management (3-M) Manual.**

300-1.2.7 DOCUMENTS AND PUBLICATIONS. The following documents and publications related to data in this chapter are available for information:

a. NAVSEA 0900-LP-060-2010, **Electrical Machinery Repair, Vol 1, Electric Motor Repairs**

b. NAVSEA 0900-LP-060-2020, **Electrical Machinery Repair, Vol 2, Vibration Analysis and Rotor Balance**

c. MIL-HDBK-290, **Standard Electrical Symbol List**

d. MIL-HDBK-299(SH), **Cable Comparison Handbook Data Pertaining to Electric Shipboard Cable**

e. DOD-STD-2003, **Military Standard, Electric Plant Installation Standard Methods for Surface Ships and Submarines**

f. MIL-E-917, **Electric Power Equipment, Basic Requirements (Naval Shipboard Use)**

g. NAVSEA S9310-AC-HBK-010, **Commutator/Slip Ring Maintenance Handbook**

h. NAVSEA S6269-AQ-HBK-010, **Slip Ring Maintenance Handbook**

SECTION 2.

ELECTRICAL SAFETY PRECAUTIONS

300-2.1 NEED FOR SAFETY PRECAUTIONS

300-2.1.1 ELECTRIC SHOCK. Safety precautions must always be observed by persons working around energized electric circuits and equipment. Injury may result from electric shock. Short circuits can be caused by accidentally placing or dropping a metal tool, flashlight case, or other conducting article across an energized line. These short circuits can cause an arc or fire on even relatively low voltage circuits, and may result in extensive damage to equipment and serious injury to personnel.

300-2.1.1.1 Danger of Electric Shock. The danger of shock from the 450-volt ac ships service system is reasonably well recognized by shipboard personnel. Still, there are reports of serious shock received from this voltage source. A number of shipboard fatalities have also been reported due to contact with 115-volt circuits. Low voltage (115 volts or less) circuits are very dangerous and can cause death where the resistance of the body is lowered by moisture, especially when current passes through the chest. All electrical energy shall be regarded as dangerous. Shipboard conditions are particularly conducive to severe shock because the body is likely to be in contact with the ship's metal structure and the body resistance may be low because of perspiration or damp clothing. Extra care is therefore needed.

300-2.1.2 CAUSE OF ELECTRIC SHOCK. Current rather than voltage is the measure of shock intensity. The passage of even a very small current through a vital part of the human body can cause death. The ability of a circuit to produce a fatal current is dependent upon the resistance of the body, contact conditions, the path through the body, etc. Fatalities have occurred from circuits with voltages as low as 30 volts. For detailed description and additional information, see Appendix G.

300-2.1.2.1 Fatal Shock Levels. The resistance of the human body is quite low and cannot be relied upon to prevent fatal shock from occurring from 115 volts or even lower voltages. When the skin is damp, body resistance can be as low as 300 ohms or even as low as 100 ohms (where skin is broken). The following are general guidelines for shocks from 60-Hz ac systems:

a. At 1 mA, shock is felt.

b. At 10 mA, a person may be unable to let go.

c. At 100 mA, shock may be fatal if it lasts for one second or more.

In addition to injury caused by the shock itself, many more people are injured as a result of falls, cuts, etc. caused by their reaction to a mild shock.

300-2.1.2.2 Symptoms of Electric Shock. In the event of severe electric shock, the victim may become very pale or ″bluish″; the victim's pulse and breathing may be extremely weak or entirely absent; he or she may become unconscious; and burns may be present. The victim's body may become rigid or stiff in a few minutes as a result of muscular reaction to the shock. This condition must not be mistaken for rigor mortis. Cardiopulmonary Resuscitation (CPR) shall be administered immediately, regardless of body stiffness, and shall be continued until medical assistance arrives.

300-2.1.3 RESCUE FROM ELECTRIC SHOCK. The rescue of electric shock victims is dependent upon prompt removal from the source of shock and administration of first aid. Personnel trained in safe removal of a victim from a source of electric shock and cardiopulmonary resuscitation (CPR) procedures should perform this emergency procedure.

300-2.1.3.1 Rescue Action. When attempting to administer first aid to an electric shock victim, proceed as follows:

a. Shut off the power, remove the victim immediately.

b. If the power cannot be shut off, observe the following precautions, and then remove the victim immediately:

WARNING

Do Not Touch The Victim

1 Protect yourself with dry insulating material.

2 Use a dry board, belt, dry clothing, or other available nonconductive material to free the victim (by pulling, pushing, or rolling) from the energized equipment.

Immediately after removal of the victim from the energized equipment, administer CPR according to paragraph 300-2.9.

300-2.1.4 INDIVIDUAL RESPONSIBILITY. Individuals have a responsibility, not only to themselves, but also to their shipmates, to always be alert to detect and report unsafe work practices and unsafe conditions. Each individual must

a. Observe all posted operating instructions and safety precautions.

b. Report any condition, equipment, or material that is believed to be unsafe.

c. Caution others to observe safety precautions.

d. Report to the supervisor any injury obtained in the course of their work.

e. Exercise caution in the event of an emergency, where deranged equipment or abnormal operating conditions could produce additional, unseen hazards.

300-2.2 SHIPBOARD ELECTRICAL SYSTEMS

300-2.2.1 EQUIPMENT GROUNDING AND SYSTEM GROUNDING. The word ″grounding″ is frequently used in ac electrical power systems for referring to both ″equipment grounding″ and ″system grounding.″ It is important to understand these two terms when considering electrical safety precautions.

300-2.2.1.1 Equipment Grounding. Equipment grounding intentionally connects the non-current-carrying conductive parts of electrical equipment, such as the enclosure, frame, or chassis, to ground (the ship's hull) through a low-resistance path. If an energized electrical conductor contacts the enclosure due to a fault or mechanical damage, the equipment ground provides the lowest impedance path of electrical current to ground, and so it shunts the current away from a possible human contact. Equipment grounding is an important safety measure.

300-2.2.1.2 Action of Electrical Equipment Safety Grounds. The shunting action of the electrical equipment safety ground reduces the current that would otherwise flow through another path - such as a person touching the enclosure and in contact with the ship's hull ground. For example, if the equipment ground has a resistance of 0.1 ohm and the person has a resistance of 600 ohms, the current would divide so that 6000/6001th would flow through the ground connection and 1/6001th would flow through the person. On a shipboard ungrounded system circuit, the maximum current that would be expected to flow as a result of the capacitance in the system (paragraph 300-2.2.3) would be such that the 1/6001th flowing through the person would be below the fatal level. Without the safety ground path, the current level would be in the fatal range.

300-2.2.1.3 Need for Grounding. If the enclosing case or other exposed metal parts are not grounded, a breakdown of insulation will raise them to line voltage and may create a hazard. Such breakdowns from a circuit or machine to an ungrounded metal object will not be detected by ground tests nor measurements of insulation resistance. They will be detectable only if the metal equipment is grounded.

300-2.2.1.4 Grounding Metal Cases, Bases, Frames, and Structures. Metal enclosing cases, bases, frames, and structural parts of electrical equipment shall be grounded in accordance with MIL-STD-1310, **Shipboard Bonding, Grounding, and Other Techniques for Electromagnetic Compatibility and Safety.** Normally on metallic hull ships, such grounds are inherently provided because the metal enclosing cases or frames are in contact with one another and the metal structure of the ship. Where such inherent grounding is not provided by the mounting arrangements (for instance, equipment supported on shock mounts), and on nonmetallic hull ships, ground connections should be provided to ground the frame, enclosure, or support of all permanently installed electrical equipment and all mobile equipment normally used at a fixed location on the ship.

300-2.2.1.4.1 To ensure that electrical equipment ground connections on nonmetallic hull ships, shock-mounted equipment, equipment mounted on extruded double-faced and honeycomb metal joiner bulkheads, and on equipment mounted on nonmetallic structures on metallic hull ships are adequate and in good condition, each ground connection should be inspected once a year. A visual inspection shall be made to insure that a ground connection exists and that it is securely fastened with a good metal-to-metal contact. The resistance to ground should be less than 0.1 ohm as specified in MIL-STD-1310.

300-2.2.1.4.2 Commercial Off The Shelf (COTS) Equipment. COTS equipment, with either metallic or non-metallic case, shall be grounded in accordance with MIL-STD-1310 when installed onboard Naval ships.

300-2.2.1.5 System Grounding. Electrical power systems can be classified by the nature of the connection between the neutral of the power system and ground. When the electrical system neutral or phase conductors are not intentionally connected to ground (except through potential measuring devices or other very-high-impedance devices), the system is said to be ″ungrounded.″ Ungrounded systems provide only a limited amount of current when one phase is faulted to ground, and thus allow critical equipment to continue operation until steps can be taken to remove the fault. Navy ships use an ″ungrounded″ system. Electric utility service for house wiring ashore uses a ″grounded neutral″ system so that a fault will produce a high current and quickly trip the circuit breaker or blow the fuse.

300-2.2.1.5.1 Receptacle outlets in an ungrounded shipboard electrical circuit are connected differently than similar receptacles in a house ″grounded neutral″ system ashore. The 115-volt receptacle in a ″grounded neutral″

house wiring system has one neutral (or ″common″) conductor which is connected to ground at the source (left-hand illustration of Figure 300-2-1). By contrast, both conductors of a shipboard receptacle have a potential between the conductors and ground (right-hand illustration of Figure 300-2-1). In either case, the ground terminal is connected to ground through a separate conductor that provides a low-impedance path to ground and does not carry the normal circuit current.

300-2.2.2 CHARACTERISTICS OF AN UNGROUNDED SYSTEM. Ungrounded systems provide reliable service. If a ground momentarily or permanently occurs to any one phase of the system, the system can still operate and current through a ground does not normally trip the circuit breaker. A common misconception of ungrounded systems is that a perfect ungrounded system is harmless. A so-called ″perfect″ ungrounded system, as described below, does not exist.

300-2.2.2.1 Ungrounded System Misconception. A common misconception of ungrounded systems is that these systems are harmless. This is because in a ″perfect″ ungrounded system, there would not be a path for current to flow if one of the power conductors were connected to ground. As shown in part A of Figure 300-2-2, if a person were to touch an energized conductor A while standing on the deck (point B), there would be no completed path in the ″perfectly″ ungrounded system for current to flow from conductor A to conductor C through the person's body. Shipboard electrical systems **are not and cannot** be ″perfectly″ ungrounded. There will always be some amount of leakage through the insulation of cables, switchboards, circuit breakers, and user equipment loads. Even if there are no electromagnetic interference (EMI) filter capacitors, there will always be some inherent capacitance to ground in any of the system's equipment and cabling. The person touching an energized conductor is always in danger of possible shock.

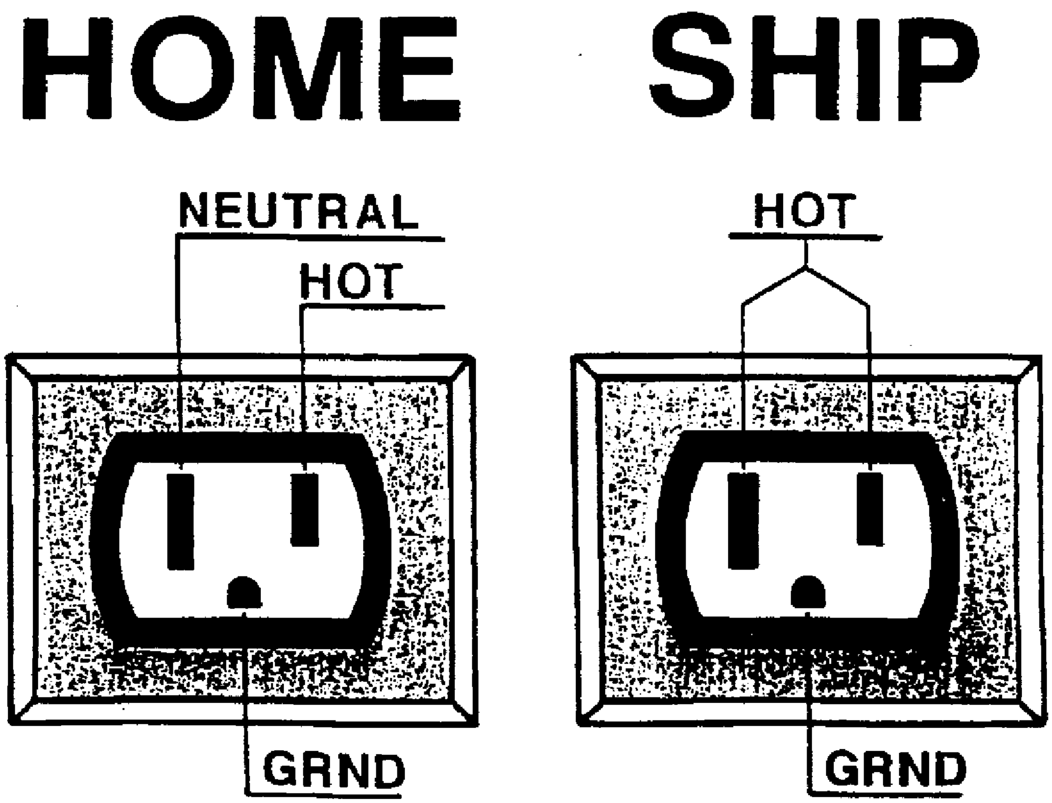


Figure 300-2-1 Home and Ship Receptacles

300-2.2.3 SHIPBOARD UNGROUNDED SYSTEMS. In a ″real″ shipboard ungrounded system, as represented in Figure 300-2-2, part B, there are resistances and capacitances between the phase conductors and ground which cannot be seen as physical components. These small current paths through electrical equipment and cables are inherent in the design of the electrical equipment and cables. In addition to these ″stray″ resistances and capacitances, many shipboard electrical systems have EMI filters which may be a part of user equipment or may be mounted separately. These EMI filters contain capacitors connected from the conductors to ground. These various paths, combined in parallel, can produce significant and dangerous currents when a phase conductor is contacted.

300-2.2.3.1 Inherent System Resistances to Ground. The resistances include generator insulation resistance, electric cable insulation resistance, and load insulation resistance. The resistances, when combined in parallel, form the insulation resistance of the system which is periodically measured with a 500-volt dc megger or installed ship active ground detector. The resistors cannot be seen as physical components, but are representative of small current paths through equipment and electrical cable insulation. The higher the resistance, the less current will flow between conductor and ground. Representative values of a large operating system can vary widely depending on the size of the ship and the number of electrical circuits connected together. The minimum acceptable resistance to ground for submarine ac or dc system is 50,000 ohms.

300-2.2.3.2 Inherent System Capacitances to Ground. Figure 300-2-2, part B also shows the capacitance of the generator to ground, the capacitance of the distribution cable to ground, and the capacitance of the load equipment to ground. These capacitances cannot be seen, since they are not actually physical components, but are inherent in the design of electrical equipment and cable.

300-2.2.3.3 EMI Filters. In addition to the nonvisible system capacitance, typical shipboard electrical systems contain electromagnetic interference (EMI) filters which contain capacitors connected from the conductors to ground. These filters may be a part of the user equipment, or they may be mounted separately. Filters are used to reduce interference to shipboard electrical and electronic equipment.

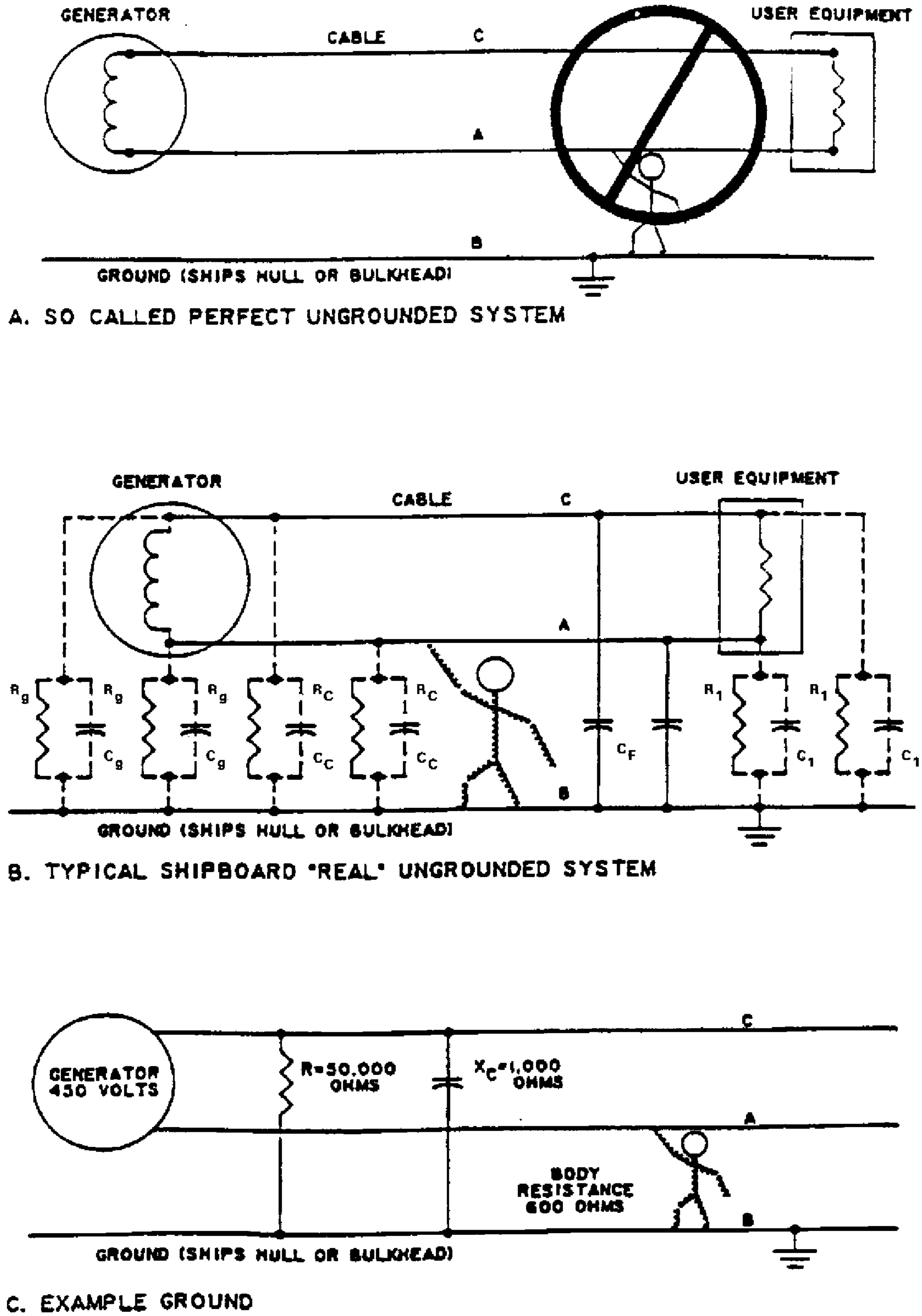


Figure 300-2-2 Ungrounded Systems

300-2.2.4 ELECTRIC SHOCK FROM SHIPBOARD SYSTEM. Because the shipboard system is designed to be ungrounded, never think that it is safe to touch one conductor on the belief that no electrical current would flow. It is never safe to touch one conductor of the ungrounded shipboard system because each conductor and all electrical equipment connected to the system provide an electrical current path between the conductors and the ship's hull. When body resistance is low (due to wet or sweaty hands, for example), the inherent capacitance is sufficient to cause electric shock or a **FATAL** electrical current to pass through the body.

300-2.2.4.1 Contact with Energized Conductor. **Never touch a live conductor** . If physical contact is made between conductor A and ground (point B), as shown in Figure 300-2-2, part C, current will flow from the generator through the person's body to ground and back through the system resistances and capacitances to conductor C, thus completing the electrical circuit back to the generator. This presents a serious shock hazard.

300-2.2.4.1.1 Suppose you megger the system of Figure 300-2-2, part C and obtain a system value of insulation resistance of approximately 50,000 ohms. You might conclude correctly that no low resistance grounds exist on the system, but the system is still not a ″perfect″ ungrounded system. Do not forget the system capacitances which exist in parallel with the resistance. You should **NEVER** touch a live conductor of an electrical system, grounded or ″ungrounded.″ Insulation resistance tests are made to ensure that insulation will not fail when energized. High insulation readings in a megger test do not make the system safe - nothing does.

300-2.2.4.1.2 The elimination of EMI filter capacitors connected to the system makes no difference from a safety standpoint. There can be more than enough current for a fatal shock without EMI filters.

300-2.3 GENERAL ELECTRICAL SAFETY PRECAUTIONS FOR EQUIPMENT MAINTENANCE

300-2.3.1 EQUIPMENT MAINTENANCE. The maintenance of electrical equipment is described in **NSTM Chapter 300, Section 4, NSTM Chapter 400, Section 3,** and equipment technical manuals. Safety from electrical hazards during any form of maintenance work can best be ensured by completely deenergizing equipment. Follow the tag-out instructions for working on deenergized equipment under paragraph 300-2.4. **When it is necessary to work on energized equipment, the requirements of paragraph 300-2.5 shall be adhered to.**

Equipment maintenance covers both preventive and corrective maintenance of electrical equipment and includes any or all of the following work:

a. Testing

b. Calibrating

c. Taking measurements

d. Troubleshooting

e. Repairing

f. Assembling

g. Disassembling

h. Making adjustments

300-2.3.1.1 Intentional Shocks Are Forbidden. **Intentionally taking a shock at any voltage is always dangerous and is STRICTLY FORBIDDEN.** Whenever it becomes necessary to check a circuit to see if it is energized, an approved test lamp, voltmeter, or other appropriate indicating device shall be used. The indicating device employed shall be suitable for obtaining the desired check without jeopardizing personnel, and if necessary, it should be used in conjunction with authorized safety devices (paragraph 300-2.3.1.5). Never trust insulation material: treat all wiring as though it were bare of insulation.

300-2.3.1.2 Authorized Personnel Only. Because of the danger of fire, damage to material, and injury to personnel, no person should be assigned to operate, repair, or adjust electrical or electronic equipment unless that person has demonstrated knowledge of its operation and repair and of all applicable safety regulations. Then and only then, when authorized by the responsible department head, should they be permitted to work on the equipment.

300-2.3.1.3 Protective Enclosure Safety. All fuse boxes, junction boxes, switch boxes, electrical enclosures, and wiring accessories shall be kept closed, except when necessary to be opened for service. Care shall be exercised to ground effectively and to maintain such protective grounds on all metal enclosures for electrical and electronic equipment in accordance with paragraph 300-2.2.1.4.

300-2.3.1.4 Safety Around Energized Equipment. Personnel should not reach within or enter energized electrical or electronic equipment enclosures for the purpose of servicing or adjusting except where such servicing or adjusting is prescribed by official applicable technical documentation (technical manuals, instruction books) and then only with the immediate assistance of another person capable of rendering first aid or assistance in the event of an emergency. Personnel shall be warned to exercise extreme caution when reaching into the enclosures of equipment having internal exposed high-voltage points.

300-2.3.1.5 Interlock Precautions. Certain electrical equipment is provided with a variety of built-in safety devices (such as interlock switches) to prevent technical and maintenance personnel from accidentally coming into contact with electrical potentials in excess of 30 volts. These devices shall not be tampered with or defeated unless required by approved procedures.

300-2.3.1.5.1 Interlocks, and other safety devices such as overload relays and fuses, shall not be altered nor shall they be disconnected except for replacement. In addition, safeguard circuits shall not be modified without specific authority from the cognizant systems command. Periodic test and inspection shall be made to ensure that safety devices are functioning properly.

300-2.3.2 GENERAL PRECAUTION REMINDERS. The following list is provided to alert all personnel to some general electrical safety precautions:

a. Do not touch a conductor, until it is tested, to be sure it is deenergized.
b. Obey all warning signs; read equipment warning labels before use.
c. Do not energize any equipment that is tagged out. Properly clear the tag first.
d. Use authorized equipment to perform maintenance work.
e. Close all fuse boxes, junction boxes, switch boxes, and wiring accessories.
f. Never operate a switch with the other hand on a metal surface.
g. Never use outlets that appear to be burnt.
h. When using a metal-cased tool, ensure it is equipped with a three conductor cord and three-pronged plug. Verify that the ground prong extends beyond the power blades of the plug.

i. Wear rubber gloves when using metal-cased portable electric equipment, or when using electric handheld portable tools in hazardous conditions, such as wet decks and bilge areas. Leather gloves shall be worn over rubber gloves when the work being done could damage the rubber gloves.

j. Do not use equipment with worn or damaged cords, or crushed or damaged plugs.

k. Check that portable electric equipment has been inspected and has a current inspection label affixed.

l. Only use electric equipment in explosive atmospheres if the equipment is approved for such use (explosion proof).

m. Do not allow cords to run over sharp objects, chemicals, or hot surfaces.

n. Do not join more than two 25-foot extension cords together. Single-length extension cords up to 100-foot are permissible.

o. Use a voltmeter or voltage tester to ensure that equipment or circuits are deenergized.

p. Observe the following precautions when drilling or cutting inside switchboards:

   1 Tape a sheet of protective material under the work area to catch falling debris.

   2 Stick a wad of soft putty behind the area to be drilled to capture the debris.

300-2.4 WORKING ON DE-ENERGIZED EQUIPMENT

300-2.4.1 EQUIPMENT TAG-OUT PROCEDURES. Safety from electrical hazards can be ensured by completely de-energizing equipment on which work is to be done. Electrical equipment should be deenergized by opening the power supply circuit breaker or switch and/or removing the appropriate fuses. Some equipment has more than one source of power, which requires multiple breakers or switches to be opened and/or multiple fuses to be removed. Remove the control fuse in the control circuit or any remote operated circuit breakers. **DANGER** tag these circuit breakers, switches and fuses. Check the equipment to be maintained with a voltmeter to ensure that it is completely deenergized before maintenance begins. For requirements concerning work on energized circuits or equipment, see paragraph 300-2.5.

300-2.4.1.1 Equipment Tag-Out. A tag-out procedure is necessary because of the complexity of modern ships and the cost, delays, and hazards to personnel that could result from improper operation of equipment. OPNAVINST 3120.32, **The Ship's Organization and Regulation Manual,** article 630.17, provides procedures to be used to prevent improper operation when a component, equipment, system, or portion of a system is isolated or in an abnormal condition. Specific Type Commander Directives further amplify the provisions of this procedure. Tag-out procedures are mandatory.

300-2.4.1.2 Danger and Caution Tags. The following discussions are based on the requirements specified in OPNAVINST 3120.32. Two tags (DANGER and CAUTION) are available for equipment tag out.

300-2.4.1.2.1 A **DANGER** tag is a **RED** tag prohibiting operation of equipment that could jeopardize safety of personnel or endanger equipment, systems, or components. Under no circumstances will equipment be operated when tagged with DANGER tags (Figure 300-2-3).

300-2.4.1.2.2 Danger tags should be attached directly to the handle of the disconnecting devices such as circuit breakers and switches through the hole in the handle. If fuse removal is used to deenergized the circuit, tape the danger tag securely to the cover of the fuse box near or over the nameplate of the circuit being tagged out, or tie the danger tag to a fuse box cover screw. It is unsafe to attach tags to fuse clips or other components inside the fuse box. Dead front (plug type) fuse holders, such as those on FC and IC switchboards, should have the tag installed over the opening left by the removed fuse(s). Do not re-install the empty fuse holder cover.

300-2.4.1.2.3 A **CAUTION** tag is a **YELLOW** tag used as a precautionary measure to provide temporary special instructions or to indicate that unusual caution must be exercised to operate equipment (Figure 300-2-4). These instructions must state the specific reason that the tag is installed. Use of phrases such as **DO NOT OPERATE WITHOUT EOOW PERMISSION** are not appropriate since equipment or systems are not operated unless permission from the responsible supervisor has been obtained. A **CAUTION** tag is not used if personnel or equipment can be endangered while performing evolutions using normal operating procedures; a **DANGER** tag is used in this case.

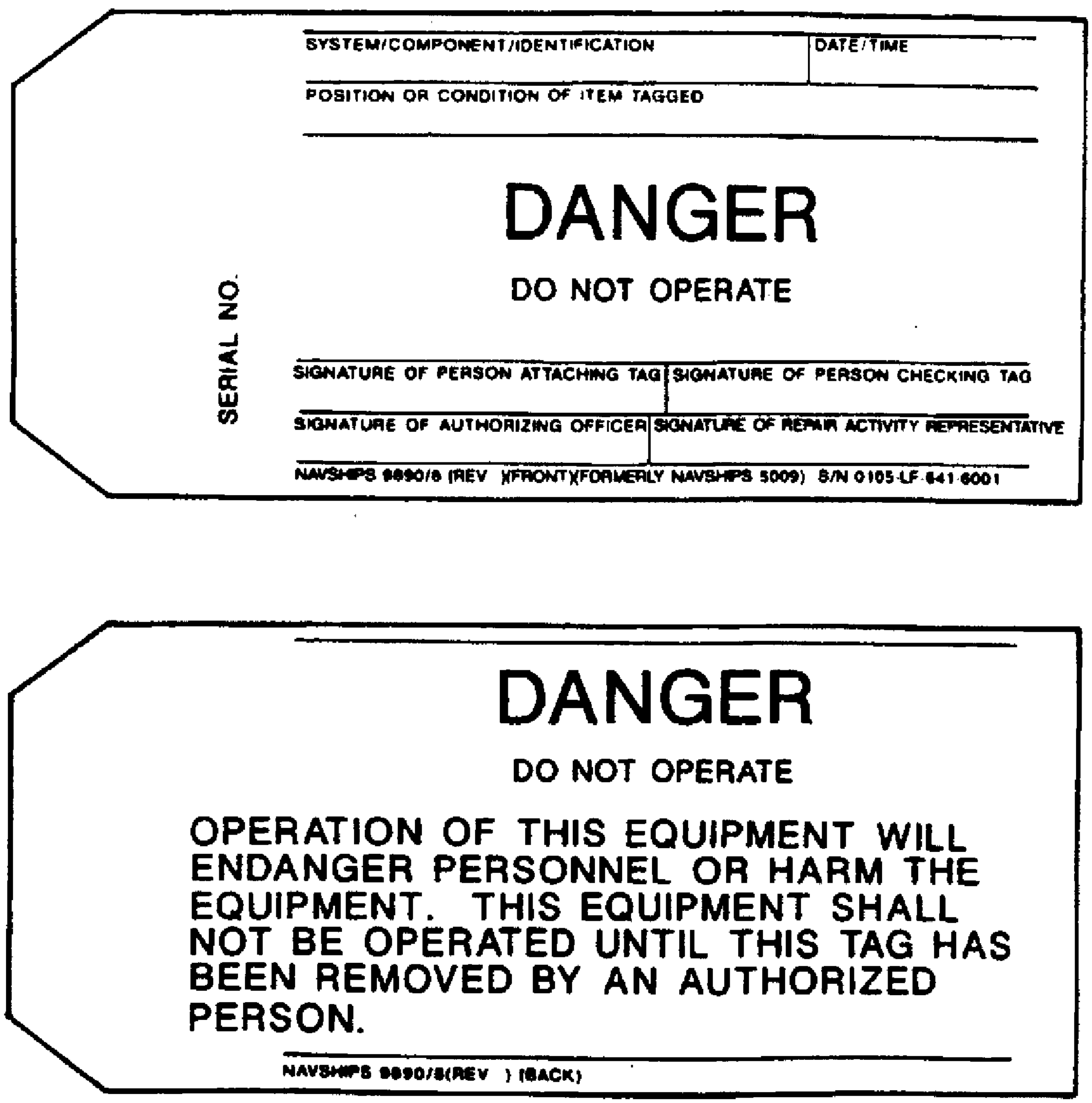


Figure 300-2-3 DANGER Tag

300-2.4.1.3 Tag-Out Procedure Summary. Work shall not be done on any energized circuit, switchboard, controller, or other piece of electrical equipment unless required by the urgency of the work and equipment importance. Equipment to be overhauled or repaired shall be deenergized by opening all switches or circuit breakers, and removing any fuses through which the power could be supplied. These switches, circuit breakers or fuses shall be tagged with **DANGER** tags as shown in Figure 300-2-3. The equipment shall be tested with a voltmeter or voltage tester, as shown in paragraph 300-2.4.2, to ensure it is deenergized. Loads supplied from controllers in group control centers shall not be worked on until the associated circuit breaker is open. If the group controller has fuses in place of a circuit breaker, the load may be isolated by removing the fuses if the load being protected is deenergized first. Tape a danger tag over the fuse location to indicate that fuse should not be installed.

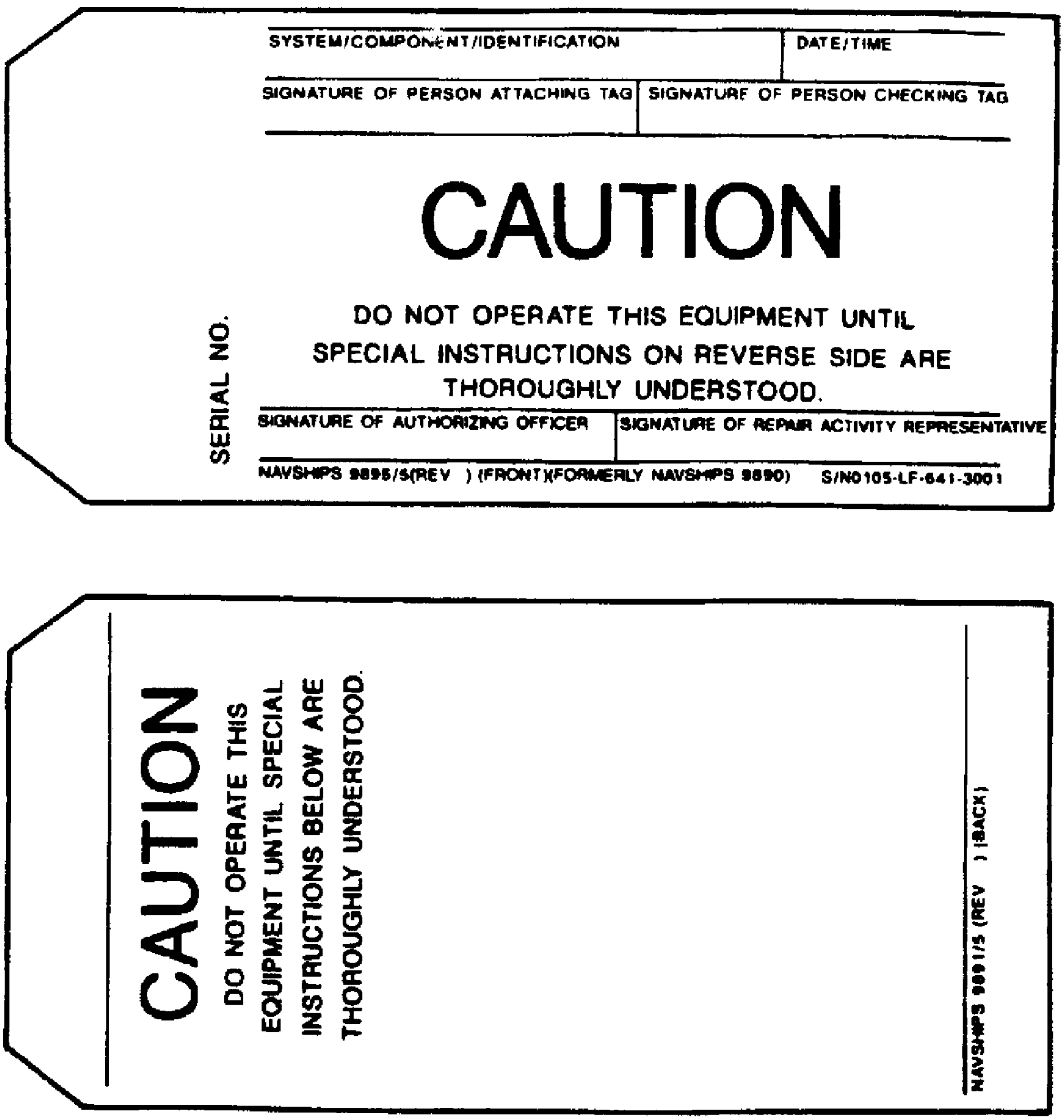


Figure 300-2-4 CAUTION Tag

300-2.4.1.4 Locking Devices. The use of DANGER tags may be augmented by the use of additional safety measures such as removing fuses, locking AQB circuit breaker handles, or discharging the closing spring for ACB circuit breakers in accordance with the applicable technical manual. Devices for locking circuit breaker handles to prevent accidental operation are listed in Table 300-2-1. Use of these locking devices and discharging the closing spring for ACB circuit breakers is optional and should be based, at the Commanding Officer's discretion, on the following criteria:

a. Whether the tagged disconnecting means are accessible to qualified persons only.

b. Whether the tag and its attachment mechanism clearly identify the disconnecting means that is open and effectively inhibiting the re-energizing of the electric circuit. For example:

   1 When a tag is used on an electrical isolating device that is capable of being locked out, the tag must be attached at the same location that the lock would be attached.

Breaker handles are normally provided with a 3/32-inch hole that permits fastening the locking device with a standard cotter pin. For older breakers, a 3/32-inch hole may be drilled in the handle, using the locking device as a drilling guide. The warning tags can be attached in the eye of the cotter pin (Figure 300-2-5).

300-2.4.1.5 Safety Related Items. Safety-related items used for electrical maintenance are stocked and readily available. For a list of safety related items for electrical and electronic maintenance and repair, see Table 300-2-1.

300-2.4.2 CHECKING FOR ENERGIZED CIRCUITS. Be sure electrical equipment is deenergized before working on it. To verify a circuit is deenergized, first connect the leads of a voltmeter or voltagetester across the power source terminals of a known energized circuit to ensure the device is working properly. The known energized circuit should be the same type and same voltage range (for example: 440vac, 115vac, 28vdc, etc.) as the circuit to be tested. Next, connect the leads of the device across the power source terminals of the equipment under test and from each terminal to ground to verify it is deenergized. Recheck the voltmeter or voltage tester on the known energized circuit to ensure that the device is still working properly.

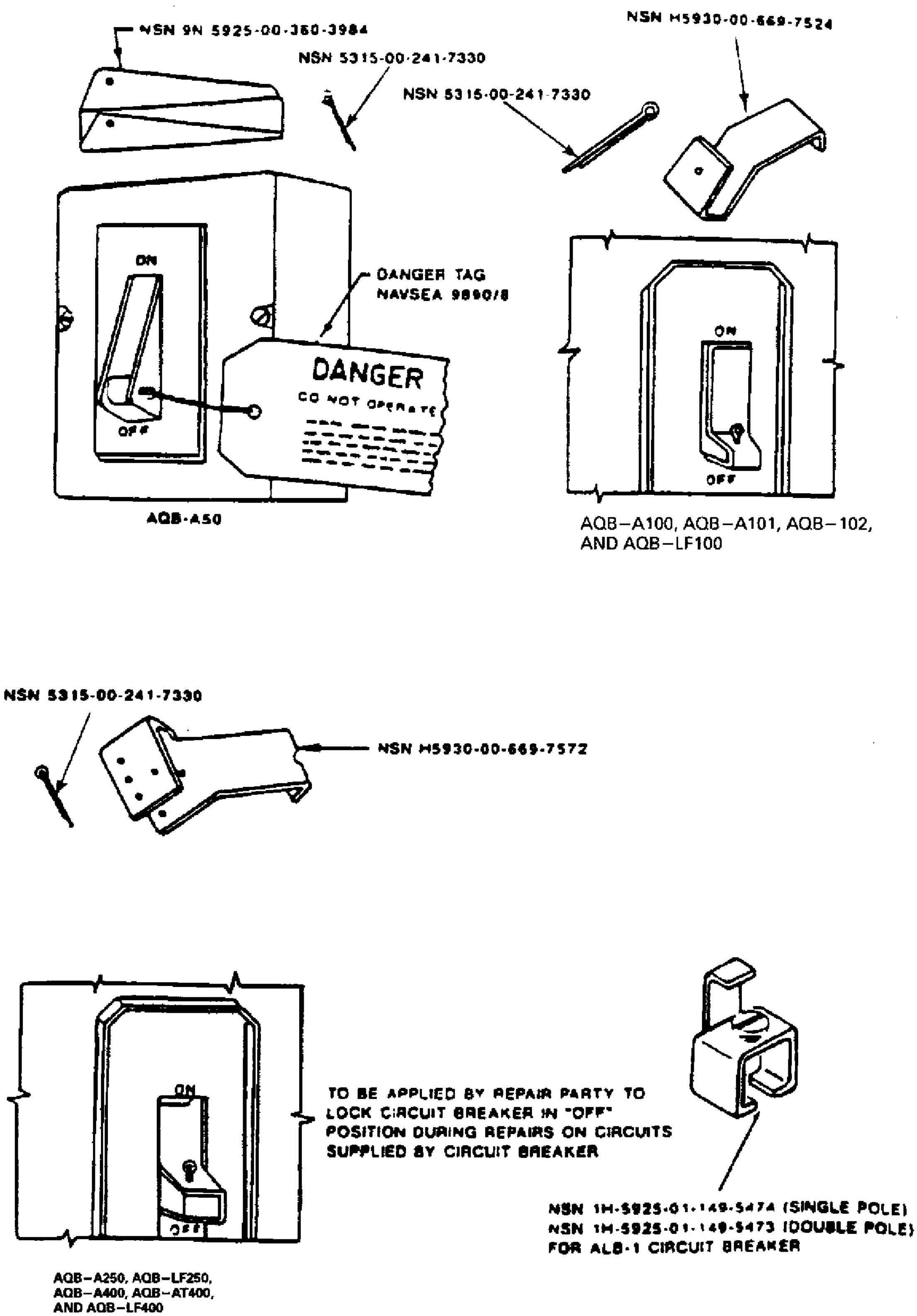


Figure 300-2-5 Handle Locking Devices for Circuit Breakers

Table 300-2-1 LIST OF SAFETY RELATED ITEMS FOR ELECTRICAL AND ELECTRONIC MAINTENANCE AND REPAIR

NSN	Nomenclature	Item Description/Use
Insulation - Gloves		
9D9415-00-782-2809	GLOVE - LINER	GLOVE LINER - COTTON
9T8415-00-264-3618	GLOVES - LEATHER SHELLS	WORN OVER RUBBER GLOVES TO PROTECT AGAINST PHYSICAL DAMAGE
9Q8510-00-817-0295	TALCUM POWER 10 OZ	USE WITH RUBBER GLOVES
9D8415-01-158-9453	GLOVES - CLASS 0 SIZE 9	RED LABEL - 1,000 VOLTS MAXIMUM SAFE USE
9D8415-01-158-9454	GLOVES - CLASS 0 SIZE 9-1/2	RED LABEL - 1,000 VOLTS MAXIMUM SAFE USE
9D8415-01-158-9455	GLOVES - CLASS 0 SIZE 10	RED LABEL - 1,000 VOLTS MAXIMUM SAFE USE
9D8415-01-158-9456	GLOVES - CLASS 0 SIZE 10-1/2	RED LABEL - 1,000 VOLTS MAXIMUM SAFE USE
9D8415-01-158-9457	GLOVES - CLASS 0 SIZE 11	RED LABEL - 1,000 VOLTS MAXIMUM SAFE USE
9D8415-01-158-9458	GLOVES - CLASS 0 SIZE 11-1/2	RED LABEL - 1,000 VOLTS MAXIMUM SAFE USE
9D8415-01-158-9459	GLOVES - CLASS 0 SIZE 12	RED LABEL - 1,000 VOLTS MAXIMUM SAFE USE
9D8415-01-158-9449	GLOVES - CLASS 1 SIZE 9	WHITE LABEL - 7,500 VOLTS MAXIMUM SAFE USE
9D8415-01-158-9450	GLOVES - CLASS 1 SIZE 10	WHITE LABEL - 7,500 VOLTS MAXIMUM SAFE USE
9D8415-01-158-9451	GLOVES - CLASS 1 SIZE 11	WHITE LABEL - 7,500 VOLTS MAXIMUM SAFE USE
9D8415-01-158-9452	GLOVES - CLASS 1 SIZE 12	WHITE LABEL - 7,500 VOLTS MAXIMUM SAFE USE
9D8415-01-158-9446	GLOVES - CLASS 2 SIZE 9	YELLOW LABEL - 17,000 VOLTS MAXIMUM SAFE USE
9D8415-01-158-9447	GLOVES - CLASS 2 SIZE 10	YELLOW LABEL - 17,000 VOLTS MAXIMUM SAFE USE
9D8415-01-158-9448	GLOVES - CLASS 2 SIZE 11	YELLOW LABEL - 17,000 VOLTS MAXIMUM SAFE USE
9D8415-01-158-9445	GLOVES - CLASS 3 SIZE 9	GREEN LABEL - 26,500 VOLTS MAXIMUM SAFE USE
Insulation - Blanket/Matting/Tape		
9G5970-00-296-5322	BLANKET INSULATING	RUBBER 36″ X 36″ (20K VOLTS)
9G5970-00-351-9578	BLANKET INSULATING	RUBBER 36″ X 27″ (16K VOLTS)
Insulation - Blanket/Matting/Tape		
9Q7220-01-057-1897	MATTING - FLOOR TYPE 3	RUBBER MATTING - GRAY - 25 YD
9Q7220-01-056-1944	MATTING - FLOOR TYPE 3	RUBBER MATTING - GREEN - 25 YD
9Q5970-01-543-1154	TAPE - INSULATING	WHITE LINEN-1/2 IN. WIDE

Table 300-2-1 LIST OF SAFETY RELATED ITEMS FOR ELECTRICAL

AND

ELECTRONIC MAINTENANCE AND REPAIR - Continued

NSN	Nomenclature	Item Description/Use
9Q5970-01-686-9151	TAPE - INSULATING	WHITE LINEN-1 IN. WIDE
Face Protection		
9Q4240-00-542-2048	SHIELD - SAFETY FACE	INDUSTRIAL TYPE
9Q4240-00-202-9473	SHIELD - SAFETY FACE	INDUSTRIAL TYPE
9Q4240-00-516-4728	SPECTACLES - CLEAR	SAFETY GLASSES 20MM NOSE BRIDGE
9Q4240-00-516-4683	SPECTACLES - CLEAR	SAFETY GLASSES 20MM NOSE BRIDGE
9Q4240-00-516-4652	SPECTACLES - CLEAR	SAFETY GLASSES
9Q8125-00-782-4000	BOTTLE - APPLICATOR	1 QUART FOR EYE FLUSH
Circuit Breaker Fuse Devices		
1H5925-01-149-5474	HANDLE LOCKING DEVICE CKT BKR	ALB-1 CKT BKR - SINGLE POLE
1H5925-01-149-5473	HANDLE LOCKING DEVICE CKT BKR	ALB-1 CKT BKR - DOUBLE POLE
9N5925-00-360-3984	SAFETY LOCKING DEVICE CKT BRK	(AQB-A50) FOR CKT BKR
9N5930-00-669-7524	SAFETY LOCKING DEVICE CKT BRK	(AQB-A100, A101, A102, LP100)
9N5930-00-669-7572	SAFETY LOCKING DEVICE CKT BRK	(AQB-A250, LF-250, A400, LF-400, AT400)
5315-00-241-7330	COTTER PIN	FOR USE WITH LOCKING DEVICES
9Q5120-00-224-9453	PULLER - FUSE SIZE 1	FOR .25″ TO .5″ DIA FUSE
9Q5120-00-224-9456	PULLER - FUSE SIZE 2	FOR .35″ TO 1.0″ DIA FUSE
9Q5120-00-243-2776	PULLER - FUSE SIZE 3	FOR 1.4″ TO 2.5″ DIA FUSE
Miscellaneous		
9G6230-01-087-6125	LIGHT-EXTENSION 4 WATT	LAMP - NONCONDUCTIVE
9G6230-00-244-3996	LIGHT-EXTENSION 8 WATT	LAMP - NONCONDUCTIVE
9Q5120-00-288-7679	EXTRACTOR - LAMP	LAMP REMOVER
9Q6230-00-270-5418	FLASHLIGHT - WATERPROOF	NON-CONDUCTIVE - AS REQD
	HARNESS - SAFETY - NON-COND.	TO BE SUBJECT OF SEPARATE CSL SUBLANT TECH NOTE
1N6625-00-284-0264	INDICATOR - VOLTAGE	PORTABLE - HAND HELD, PLASTIC CASE
9Q5120-00-879-4998	MIRROR INSPECTION - NON-COND	1.25″ DIA X 13″ PLASTIC HANDLE
9G5975-01-029-4176	PROBE - SAFETY SHORTING	25 KILOVOLTS
9D8415-00-082-6108	APRON - RUBBER	GENERAL PURPOSE FOR STORAGE BATTERY AND BATTERY ACID HANDLING
OI0177-LF-225-2100	SIGN - ELECTRICAL SAFETY	″DANGER HIGH VOLTAGE″ 5″ X 7″
OI0177-LF-225-6700	SIGN - ELECTRICAL SAFETY	″DANGER HIGH VOLTAGE″ 4″ X 8″

Table 300-2-1 LIST OF SAFETY RELATED ITEMS FOR ELECTRICAL AND ELECTRONIC MAINTENANCE AND REPAIR - Continued

NSN	Nomenclature	Item Description/Use
OI0177-LF-225-1101	SIGN - ELECTRICAL SAFETY	″DANGER, WORKING ON ENERGIZED EQUIPMENT, UNAUTHORIZED PERSONNEL KEEP OUT″
OI0177-LF-225-2800	SIGN - ELECTRICAL SAFETY	″DANGER HIGH VOLTAGE″ 2 1/2 X 4″
L0177-LF-008-1700	SIGN - ELECTRICAL SAFETY	″CARDIOPULMONARY RESUSCITATION″
L0177-LF-008-1200	SIGN - ELECTRICAL SAFETY	″WARNING SHOCK VICTIM REMOVAL″

300-2.4.2.1 Check Metering and Control Circuits. When checking to see whether circuits are deenergized, check metering and control circuits, as well as power circuits. In many cases, metering and control circuits are connected to the supply side of a circuit breaker or supplied from a separate source. A check of the load side of a circuit breaker may indicate that the power circuit is dead after the circuit breaker is opened, but such a check gives no assurance that associated metering and control circuits are dead.

300-2.4.2.2 Handling Removable Test Leads. Make sure that removable test lead connections on portable meters are tight. Shock and fire hazards are created if the meter end of an energized test lead is allowed to come adrift during a check of energized circuits. Only the portions of test leads necessary to make contact with the electric circuit or meter should be uninsulated; all other portions should be insulated.

300-2.4.3 DISCHARGING DE-ENERGIZED CIRCUITS. The electrical charge retained by secured electrical equipment may be great enough to cause a severe shock. This danger must be considered before touching the terminals to an apparently de-energized equipment. Discharge the equipment to ground by momentarily connecting the terminal to ground using a shorting probe (see Table 300-2-1). Capacitors and picture tubes can develop a charge after a period of time and may need to be shorted several times before being fully discharged.

300-2.4.3.1 Discharging Connected Capacitors. Capacitors are used in electromagnetic interference suppression accessories and circuit filters, in electrical power and lighting equipment, in interior communication and fire-control equipment, in other electronics equipment. Before touching a capacitor that is connected to a deenergized circuit, or one that is disconnected entirely, short circuit the terminals by using a shorting probe or the built-in grounding bar provided for this purpose.

300-2.4.4 MINIMIZE ACCESS. Minimize access to open electrical equipment. Posting signs, erecting barricades, or securing covers of unattended equipment are acceptable methods for minimizing access.

300-2.5 WORKING ON ENERGIZED EQUIPMENT

300-2.5.1 APPROVAL PROCEDURES. Electrical equipment is a source of great danger if not properly approached. The Commanding Officer is responsible for electrical safety. Energized electrical equipment shall not be disassembled nor undergo any maintenance without approval of such action by the Commanding Officer or, in his absence, the Command Duty Officer. Exceptions to this policy are those cases where approved instructions issued by higher authority (equipment technical manuals, PMS, or an established troubleshooting procedure) permit opening or inspecting equipments in the course of performing maintenance, routine testing, taking measurements, or making adjustments that require equipment to be energized. During ship availabilities where work on energized equipment is anticipated, authorization to accomplish such work should be provided in advance, where possible, to minimize work delays. Commanding Officer permission is not required when checking equipment or circuits to verify deenergization.

300-2.5.2 ENERGIZED CIRCUIT WORKING PROCEDURES. When repair or maintenance must be done on energized circuits or equipment, the following precautions shall be observed in addition to the general precautions of paragraph 300-2.3. These precautions do not apply for circuits and equipment that are adequately covered or isolated from adjacent energized circuits by authorized insulating materials and for circuits or equipment less than 30 volts.

a. Never work on energized electrical or electronic equipment by yourself; have another person (safety observer) qualified in first aid for electrical shock present at all times. The safety observer should also know which circuits and switches deenergize the equipment and will be given instructions to operate the switch immediately if anything unforeseen happens.

b. Workers shall not wear wristwatches, rings, watch chains, metal articles, or loose clothing that might accidentally contact energized parts or throw some part of their bodies into contact with mechanical/electrical active components. Clothing and shoes shall be as dry as possible.

c. Insulate the deck or standing surface from ground by covering with insulating material. Rubber mat or rubber blankets (Table 300-2-1) shall be used for this covering. If mats or blankets are not available, and the work must be accomplished before the specified material is available, other suitable insulating materials are dry wood, dry canvas, dry phenolic material, or even several layers of heavy, dry paper. Be sure insulating material is dry, has no holes in it, and that no conducting materials are embedded in it. Cover enough area so that workers have adequate space to move about.

d. Use only one hand to do the work, if practical.

e. If the work being done permits, rubber gloves shall be worn on both hands; if not, a rubber glove shall be worn on the one hand not used for handling tools.

f. A faceshield or spectacles (see Table 300-2-1) shall be worn during work on energized equipment, since a short circuit could produce a high fault current capable of producing flying molten particles and intense heat.

g. Cover metal on hand-held tools with an electrical insulating material. One acceptable method is to use two layers of rubber or vinyl plastic tape, half-lapped. Another method is to coat tools with Plastisol; see instructions in **NSTM Chapter 631, Preservation of Ships in Service.** In an emergency, if time does not permit applying the foregoing materials, the tool handles and tool shafts may be covered with cambric sleeving, synthetic resin flexible tubing, or with insulation tubing removed from scraps of certain kinds of electric cable.

h. Take the following extra precautions when the nature of the work is particularly hazardous, such as when working in the interior of a switchboard or other cubical where exposed energized bus bars are in the vicinity of the work or the work actually requires contact by tools to the energized components:

   1 Station personnel with communications, as necessary, so that the circuit or switchboard can be deenergized immediately in an emergency.

   2 Provide insulated barriers between the work and any energized metal parts adjacent to the work area as practicable.

   3 Erect barriers to keep unauthorized personnel out of the maintenance area. Erect barrier at a minimum dis-

tance of three feet from the energized electrical work site. Place a sign at the barrier that states: **DANGER, Working on Energized Equipment, Unauthorized Personnel, Keep Out** (see Table 300-2-1).

4 A non-conducting safety line or equivalent shall be attached to a safety harness or tied around the upper body in case the person performing the maintenance must be pulled from the work area. A person tending the other end of the safety line or equivalent shall be located at a safe distance outside the safety barrier such that any inadvertent action (such as falling) would not jeopardize the person doing the work.

i. While work is being done, a person trained in mouth-to-mouth resuscitation and cardiac massage shall be immediately available in case of electric shock.

300-2.5.3 RUBBER INSULATING GLOVES. Rubber insulating gloves are fabricated from natural rubber. Natural rubber is the best material available that combines the chemical, physical, and dielectric properties required. However, natural rubber is susceptible to attack by oxygen, ozone, and petroleum products. The usual antioxidant additives used in compounded rubber will prevent oxygen attack for reasonable periods of time, but they are almost totally ineffective against ozone. Ozone may cause serious cracking of rubber compounds, especially if they are under strain due to binding or stretching. Ozone is often formed in the vicinity of electrical apparatus because of electrical discharge or ionization of the surrounding air. Further exposure to petroleum products can cause rapid deterioration of the rubber material.

300-2.5.3.1 Glove Classification. There are four classes of rubber insulating gloves available in the stock system, the primary feature being the wall thickness of the gloves and their maximum safe voltage, which must be identified by a colored label on the glove sleeve. Use only rubber insulating gloves that are marked with a colored label. Table 300-2-1 contains the stock numbers, maximum safe use voltage, and label colors for insulating gloves approved for Navy use. The rubber insulating gloves' maximum safe use voltage classification must be greater than or equal to the line-to-line voltage rating of the circuit on which they are to be used.

300-2.5.3.2 Common Causes of Glove Damage. Carefully inspect gloves for damage or deterioration before use. Discard damaged or deteriorated gloves. The following data shows the type of damage to rubber gloves caused by neglect or mishandling. Glove damage can be avoided or minimized if an effective program of glove care is instituted and conscientiously followed:

a. Snags. Snags are caused by splinters, burrs, and other sharp objects.

b. Compression cracking and ozone damage. This type of damage is caused by prolonged compression, or by storage in the vicinity of ozone-producing equipment.

c. Fold cracking. Cracking is caused by prolonged folding. The strain on the rubber material in the folded area is equal to stretching the glove to twice its length.

d. Reversed glove storage. Storing a reversed glove may cause compression or stretching of the rubber material and should be avoided.

e. Chemical damage. Swelling and deterioration will result from exposure to, or contact with, petroleum products.

f. Sun damage. The type of damage caused by prolonged exposure to sunlight can only be checked by reducing the amount of exposure during use and storage.

300-2.5.3.3 Glove Inspection. To inspect rubber insulating gloves for damage, the following procedure shall be used:

1. Hold one glove downward and grasp the glove cuff.
2. Flip the glove upward toward the body to trap the air inside the glove.
3. Squeeze the rolled cuff tightly into a U-shape to keep the trapped air inside; then squeeze the inflated glove and inspect for cracked, torn, deteriorated, or damaged surfaces.
4. Hold the inflated glove close to the ear and face then, by squeezing the glove, listen and feel for indications of escaping air.
5. Turn the rubber insulating glove inside out for continued inspection, proceeding as follows:
   a Grasp the glove cuff and pull it over the fingers.
   b Remove powder, if applicable.
   c Repeat steps 1 through 4 listed above.
   d Turn glove right side out.
   e Apply a generous amount of talcum powder to interior of glove.
6. Repeat steps 1 through 5 for other glove.

300-2.5.3.4 Glove Care. For proper maintenance of rubber gloves, adhere to the following rules:

a. Inspect gloves frequently for damage.
b. After each use, rinse gloves with freshwater inside and out. Dry each glove, inside and out, by blotting with clean, dry toweling.
c. As applicable, wear leather protectors over rubber gloves.
d. Lay rubber gloves flat and store them in suitable containers.
e. Do not store or expose rubber gloves in sunlight for prolonged periods.
f. Do not store rubber gloves near petroleum products or ozone-producing equipment.

300-2.5.4 FUSE REPLACEMENT. Fuses are safety devices installed in power and lighting circuits and in control circuits to protect the equipment and circuit cabling from damage due to excessive current. Guidance given in technical manuals for user equipment (such as weapon systems, switchboards, motor controllers, etc.) should be followed when replacing fuses in the user equipment control circuits. When a fuse is removed from a circuit, it must only be replaced with a fuse of the proper type (A, B, or C). Never replace with a higher fuse current rating. Never replace a Type C fuse with a Type A or B fuse, or short out a blown fuse. Type C fuses are designed to interrupt 100,000 amps of fault current, but Type A or B fuses can only interrupt 10,000 amps. Replacing a Type C fuse with a Type A or B fuse could result in fuse explosion, fire or damage to the user equipment or distribution system the fuse was intended to protect. No fuses should be removed from or replaced in circuits that are energized unless permitted by the exceptions of paragraphs 300-2.5.4.3, 300-2.5.4.4, or 300-2.5.4.6.

300-2.5.4.1 General. Most shipboard fuses, especially those in the power and lighting distribution system, have silver-plated ferrules to minimize corrosion in the shipboard environment. Some Navy equipment, especially commercial or commercially-derived equipment, may be furnished with fuses that do not have silver-plated ferrules. Corrosion between fuse ferrules that are not silver-plated and the fuse clips can cause high resistance and local heating that can cause the fuse link to melt, and can affect other adjacent fuses. A silver-plated fuse or fuse clip must be replaced with a silver-plated fuse or fuse clip respectively. Silver-plated metals develop a black oxide coating over time which does not affect performance and should not be removed. Silver plating is designated by the letter ″S″ following the current rating of the fuse (e.g., F60C 500V 5AS).

300-2.5.4.2 Removing or Replacing Fuses in De-Energized Circuits. Unless permitted by the exceptions of paragraphs 300-2.5.4.3, 300-2.5.4.4, or 300-2.5.4.6, fuses should be removed or replaced only when the circuit is completely deenergized (that is, no voltage at the line side fuse clips). The following procedure should be used to remove or replace fuses in deenergized circuits:

1. Deenergize the fuse box by opening and tagging out the upstream circuit breaker or fuses supplying power to the fuse box if the fuse is inside the fuse box.
   a Open the fuse box cover and check that there is no voltage present on the line side of the fuse clips before proceeding further.
   b Pull out or insert fuses using the fuse pullers listed in Table 300-2-1. Fuses mounted in plug-type holders (e.g., on IC and FC switchboards) are removed by unscrewing the plug.
   c After fuse replacement, the circuit should be energized only when the cover over the fuses is closed. Neglect of this precaution can lead to injury caused by explosion when the circuits are energized.
   d If the replacement fuse opens (blows), then a fault exists which must be corrected prior to replacing another fuse.

300-2.5.4.3 Exceptions for Critical Equipment Circuits. Removing or replacing fuses in energized circuits is permitted if deenergizing the circuits to the line side fuse clips would require shutdown of other critical equipment. Critical equipment includes equipment such as machinery plant controls, electric plant controls and indicators, guidance systems that would require reprogramming should power be interrupted, or any equipment designated by the Commanding Officer to be necessary for safe ship operation or performance of the ship's mission. (″Vital equipment,″ which is supplied power from either of two sources via a bus transfer switch, may not necessarily be considered ″critical″ for purposes of energized fuse replacement). In these instances, the precautions outlined in paragraph 300-2.5.4.5 shall be followed.

300-2.5.4.4 Exceptions for User Equipment Maintenance. In some cases, there are no switches or circuit breakers provided between the distribution box and the user equipment. In these situations, it may be necessary to remove fuses to secure power to the user equipment while performing preventive maintenance. Where the distribution box cannot be deenergized by an upstream breaker without causing a disruption to other user equipment fed from the distribution box, and the circuit is in good working order (that is, no blown fuses), the fuses can be removed from the energized box. The precaution outlined in paragraph 300-2.5.4.5 must be followed to perform this work. Equipment tag-out procedures given in paragraph 300-2.4.1 should be followed for the user equipment undergoing maintenance. After removing the fuse, the red **DANGER** tag should be taped securely to the fuse box cover or over the nameplate of the circuit being tagged out or tied to the fuse panel cover screw to prevent other personnel from replacing the fuse while maintenance work is being conducted on the user equipment.

300-2.5.4.5 Removing or Replacing Fuses in Energized Circuits. The safest method of removing or replacing fuses is with the circuit completely deenergized (that is, no voltage on the line side of the fuse clips). Where paragraphs 300-2.5.4.3 or 300-2.5.4.4 apply or when replacing a blown fuse, fuses may be removed or replaced while the circuit is energized. Only properly trained and qualified personnel shall remove or replace fuses on energized circuits.

WARNING

When removing or replacing fuses in energized circuits, personnel will come in close proximity to energized fuse clips and cable terminations. An arc can be produced if the fuse is pulled or re-installed with user equipment still connected to the circuit. Strict adherence to procedures is essential to maintain personnel safety and to avoid damage to equipment.

The following procedures must be followed:

1. If permitted by the design of the circuits, remove all user equipment on the circuit by opening all user equipment switches and/or unplugging all portable cords prior to opening the fuse box cover.

2. Steps a through g and step i of paragraph 300-2.5.2 must be followed.

3. If replacing a blown fuse in a fuse box, first check the load side fuse clips of the circuit with the blown fuse using a voltmeter to ensure there is no voltage. Then, measure across the same fuse clips with an ohmmeter to ensure that the cable does not have a short after removing both fuses.

WARNING

Replacing a blown fuse in an energized fuse box can result in a flash, arcing, or fuse explosion if the short is still present or the load is not secured. This can cause personnel injury or fire.

4. If removing a fuse to isolate user equipment for maintenance, tape or tie the red **DANGER** tag to the fuse box cover near or over the nameplate of the circuit being isolated. This should serve to notify other personnel not to replace the fuse while maintenance work is being conducted on user equipment.

300-2.5.4.6 Exceptions for Dead-Front Fuse Holders. Exceptions to the requirements of paragraph 300-2.5.4.5 are permitted for fuses in plastic insulated fuse holders located on external surfaces of switchgear, panels, controllers, or other equipment provided that:

a. the circuit is rated 480V or less

b. the fuse holders are in good condition

c. the fuse holders have not been modified for testing purposes

d. fuses on 480 volt or less circuits of the same configuration rated 10 ampere or less may be removed or replaced without deenergizing the load.

e. the user equipment protected by the fuse has been secured (that is, no current is being drawn). With the fuses removed and the fuse holder carriages reinstalled, a reduced voltage is still being supplied to the equipment because of the blown-fuse indicator circuit.

CAUTION

Even with the fuses and fuse holder carriages removed, a hazardous electrical potential may still exist at the fuse holder input power connections.

After the fuse replacement, the circuit should be energized only when the cover over the fuses is closed. Neglect of this precaution can lead to injury caused by explosion when the circuit is energized.

300-2.6 SPECIAL PRECAUTIONS WHILE WORKING ON DAMAGED EQUIPMENT

A maximum degree of alertness and care is required to work on damaged equipment. When working on electrical equipment or circuits that have been damaged and may be deranged internally to impose a possible personnel safety hazard, observe all electrical safety precautions (paragraphs 300-2.3 and 300-2.4), and all precautions for maintenance on energized circuits (paragraph 300-2.5) until it is verified that all portions of the circuit are deenergized. Equipment or circuits that are not operating properly, but have not had a casualty, are probably not internally deranged and do not need to be considered as work on damaged equipment.

WARNING

Dangerous voltages may be present on the covers and frames of deranged electrical equipment.

300-2.7 PORTABLE ELECTRICAL EQUIPMENT

300-2.7.1 GENERAL PRECAUTIONS FOR PORTABLE ELECTRICAL EQUIPMENT. Portable electrical equipment is a device that will be plugged into a shipboard isolation receptacle and operate with the ship's electrical power. The hazards associated with the use of portable power equipment include electrical shock, bruises, cuts, particles in the eye, falls, and explosions. Safe practice in the use of this equipment will reduce or eliminate such accidents. Listed below are some of the general safety precautions that shall be observed when work requires the use of portable electrical equipment. The use of portable electrical equipment can be potentially hazardous. These safety procedures and policies should be practiced.

a. Wear rubber gloves when using electric handheld portable tools in hazardous conditions, such as wet decks and bilge areas. Leather gloves shall be worn over rubber gloves when the work being done could damage the rubber gloves.

b. Wear eye protection when working where particles may strike the eyes.

c. Wear hearing protection (ear plugs or circumaural type muffs that cover the entire outer ear) when working with noise producing tools or in the area of such work.

d. Do not use spliced cables.

e. Do not use any portable electrical equipment that has a frayed cord or broken/damaged plug.

f. Make sure that the on/off switch on the portable equipment is in the off position before inserting or removing the plug from the ac power receptacle.

g. Always connect the cord of a portable electrical equipment into the extension cord before the extension cord is inserted into an energized receptacle.

h. Always unplug the extension cord from an energized receptacle before the cord of the portable electrical equipment is unplugged from the extension cord.

i. Arrange the cables so that they will not create a tripping hazard.

300-2.7.2 ISOLATED RECEPTACLE CIRCUITS. To reduce the inherent hazard of leakage currents on receptacle circuits where portable electrical equipment is plugged in, isolated receptacle circuits are installed on all new-construction ships. These circuits are individually isolated from the main power distribution system by transformers and each circuit is limited in length to reduce the line-to-ground capacitance to an acceptable level. This design limits ground leakage currents to less than 10 mA, which will produce a non-lethal shock to personnel and should enable them to let go. Ships already in the fleet were provided information for installation of either fixed or portable isolation transformers in the receptacle circuits in 1960. The use of isolated receptacle circuits, and equipment design improvements, have reduced the hazards encountered when using portable electrical equipment. However, the best safety device is respect for the hazards present in all electrical systems.

300-2.7.2.1 Grounding of Receptacles. The installation of grounded-type receptacles has been authorized for all power outlets in surface ships and for submarines. Grounded-type receptacles should be used in conjunction with grounded-type plugs to ground metal-cased portable tools and equipment. If grounded receptacles are not yet installed, proper receptacles should be selected from the Federal Stock Catalog, Class 5935, and requisitioned through the supply system. See **NSTM Chapter 320, Electric Power Distribution Systems,** for information on the proper type of receptacle to obtain and where receptacles should be installed.

300-2.7.2.1.1 Plugs and receptacles which do not have a grounding terminal, or three-prong to two-prong adapter plugs, must not be used if the tool or equipment requires an equipment grounding conductor. Grounding the equipment to the ship's metal structure by other methods (for example, by means of a spring clip or by securing the grounding conductor to a convenient screw or bolt) is an unacceptable means of equipment safety grounding.

300-2.7.2.1.2 The types of grounded receptacles listed in **NSTM Chapter 320** have metal cases which are connected internally to the ground terminal of the receptacle. Grounding the case of the receptacle will ground the grounded terminal. Some receptacles in use are of the grounded type with plastic cases. All such grounded receptacles shall be inspected to make sure that the conductor used to connect the grounded terminal to ground has a cross section greater than the cross section of the line conductors which carry power to the receptacle.

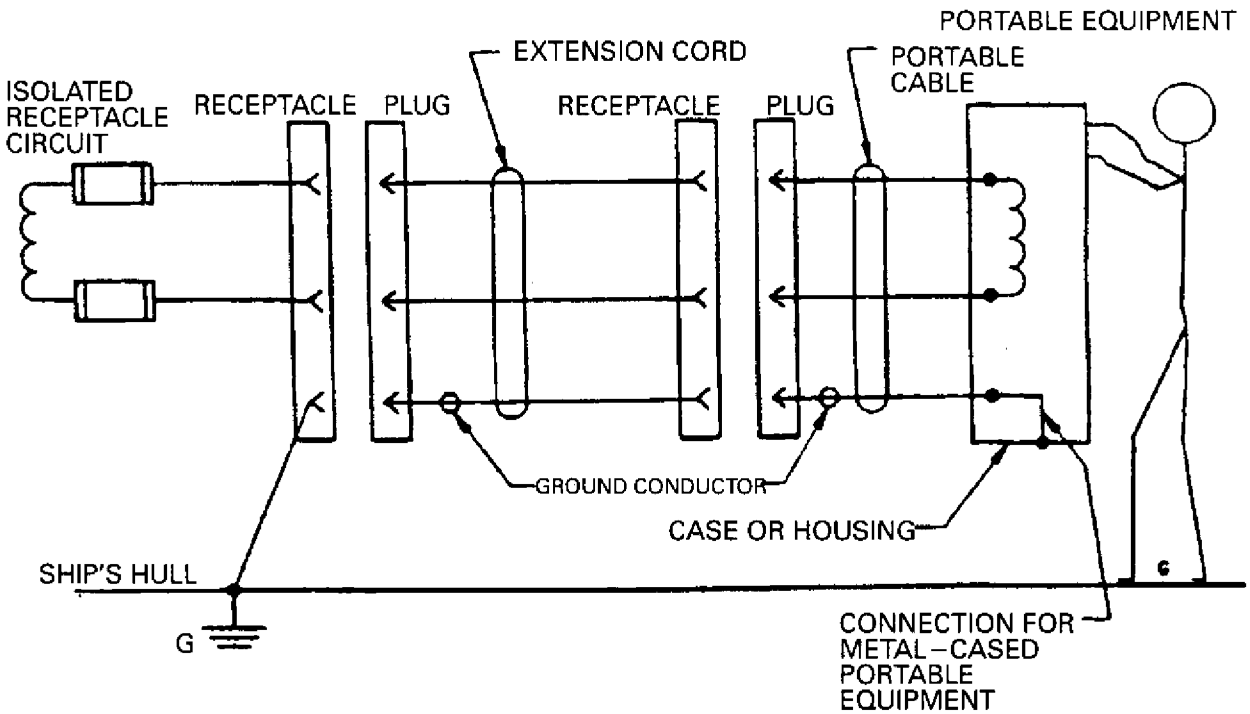
300-2.7.2.1.3 Procedures to verify proper connections to the receptacle are provided in paragraph 300-2.7.6.1 and shall be performed whenever a receptacle is installed, repaired, or modified in any way. In addition, a routine check of the receptacle ground connection in accordance with the procedures of paragraph 300-2.7.6.2 shall be performed every 6 months on each installed receptacle that is exposed to the weather and annually for all other receptacles.

300-2.7.3 PORTABLE ELECTRICAL EQUIPMENT TYPES

300-2.7.3.1 Portable Electrical Tools/Devices. Portable electrical tools and devices have an attached cord, are hand-held or frequently handled while operated, and are plugged into an electric power receptacle [example: drills, grinders, sanders, ventilation blowers (Red Devil), deck buffers, circular saws, deck strippers, drop lights, vacuum cleaners, soldering guns/irons, coffee makers, etc.]. All such equipment are subject to safety checks. If the portable tool/device uses self-contained dc power, such as a battery, then no safety check is necessary. However, if the electric tool/device uses self-contained dc power, but must be recharged through a plugged-in battery charger and the battery charger is operated from shipboard electrical power, then a safety inspection is required no matter how low the output dc voltage.

300-2.7.3.2 Metal-Cased Portable Tools/Devices. For shipboard application, an equipment safety ground conductor is imperative for metal-cased equipment or equipment with exposed metal parts to ensure personnel safety. The portable cable supplying power to these equipments shall be provided with a distinctively-marked grounding conductor in addition to the conductors supplying power to the tool. The equipment safety ground conductor may not be required for portable tools/devices which meet the requirements of paragraph 300-2.7.3.3 or paragraph 300-2.7.3.4.

300-2.7.3.2.1 Grounded-type plugs and receptacles automatically connect the ground conductor to the ship's hull when the plug is inserted into the receptacle. The use of these grounded-type plugs and receptacles has been standardized by NAVSEA. The correct connections from the portable tool/device to the plug and the mating of the plug to the receptacle are shown schematically in Figure 300-2-6. The end of the grounding conductor within the tool/device must be electrically connected to the metal housing and all exposed metal parts which the operator may touch while operating the device; the other end of the grounding conductor is connected to the ground prong of the tool/device's power plug. Care should be taken to secure a good contact between the grounding conductor and the metal to which it is connected by scraping away any paint and scratching a clean surface (down to bare metal).



Three conditions must be met to ensure that the grounding conductor will be connected correctly, namely:

1. **The connections in the receptacle must be correct.**
2. **The connections between the flexible cord and the plug at one end, and between the cord and the tool at the other end, must be correct.**
3. **The plug must be inserted into the receptacle in the correct position.**

Figure 300-2-6 Schematic Diagram of Grounded Plug and Receptacle

300-2.7.3.2.2 In those cases where grounding of the tool or device is necessary and the portable cord supplied with the tool or device does not include the extra conductor for equipment grounding, the tool or device shall not be used until it is rewired to provide the equipment safety ground conductor.

WARNING

Never use any metal-cased portable electrical tool, device, or extension cord unless you are absolutely sure that it is equipped with a properly-connected grounding conductor.

300-2.7.3.3 Double-Insulated Portable Tools/Devices. Portable tools or devices with the words **double insulated** or **double insulation** stamped on their enclosure do not require a separate equipment grounding conductor. The ″double insulated″ stamping is an Underwriters Laboratories designation. ″Double insulation″ refers to the existence of two separate insulating systems within a tool or device such that failure of one insulation would not result in hazardous voltages on any exposed metal components. Double insulation is designed into the construction of a device and cannot be easily determined by inspection.

300-2.7.3.3.1 Two-prong plugs and two-conductor cords on double insulated tools and devices aboard ships and may be inserted in blade-type receptacles even though the receptacle is labeled ″WARNING. INSERT THREE-PRONG GROUNDED PLUGS ONLY.″

300-2.7.3.3.2 There are instances where double insulated equipment may have exposed metal parts, such as wear shields or fastening screws. Grounding wires need not be attached to these exposed metal parts.

300-2.7.3.4 Non-Conducting Cased Portable Tools/Devices. Portable equipment that is not stamped ″double insulated″ may be exempted from the requirement for a grounding conductor provided the equipment case and handle is made of non-conducting material and the equipment meets both of the following requirements:

a. Passes an initial inspection for rugged, safe construction.

b. Has a minimum of 1 megohm dc resistance from any phase conductor to any exposed metal part (such as chuck housing, mounting screws, ear plug jacks, or antennas) or metal chassis.

300-2.7.3.4.1 When equipment meets the requirements of paragraph 300-2.7.3.4, it is acceptable with a two-prong plug and two-conductor cord. However, if the equipment was provided with a grounding cord and plug, this type cord and plug shall be retained throughout the life of the device.

300-2.7.3.4.2 At the discretion of the inspection authority, three-prong plugs and three-conductor cords may be installed on non-conducting cased equipment which is not stamped ″double insulated″ if it is determined that the ground conductor can be conveniently connected to the exposed metal parts and the modification does not compromise the equipment operation or enclosure integrity.

300-2.7.3.4.3 A two-conductor flexible cable and two-prong plug may be used for portable lights or other portable electrical equipment of rugged construction which has no exposed metal parts.

300-2.7.3.4.4 If there is any doubt about the equipment's ability to safely maintain the insulation of its exposed metal parts from the energized conductors, or its ability to contain the energized conductors within the enclosure, the equipment shall not be used without the exposed metal parts grounded by the addition of a portable cord and plug with grounding conductor.

300-2.7.3.5 Mobile Electrical Equipment. Mobile Electrical Equipment is defined as a unit which is not hardwired, can be moved, but normally is stationery while operating. Examples include: adding machines, copiers, typewriters, fans, toaster, welding machines, bench grinders, juice dispensers, ships entertainment equipment, TVs, vending machines, refrigerators, automatic teller machines, etc. Any single-phase 115-volt mobile equipment which is permanently located and is energized more than 50 percent of the time (such as copiers, personal computers and peripherals, soda machines, and automatic teller machines) shall not be connected to the ship's existing isolated receptacle circuits. Connecting this equipment to the ship's existing isolated receptacle circuits may overload the circuits, resulting in fire hazards. Each piece of equipment of this type should be connected to a separate single-phase circuit through an isolation transformer supplied by the lighting distribution system. The ship's isolated receptacle circuits can be temporarily modified to power such mobile equipment as follows:

a. Where a multi-outlet powerline strip is required, only one is allowed on one isolated receptacle circuit.

b. The equipment load must not exceed 13 amperes. When numerous pieces of equipment (such as personal computer work stations) are connected to one receptacle, the equipment load is equal to the summation of name plate full load ampere ratings of each equipment at 115 volts. When an equipment has various speeds or power settings with different current requirements for each setting, the highest current rating shall be used.

c. The total receptacles per circuit (including the receptacle supplying the mobile equipment and those unused on multi-outlet powerline strips) must be limited to: 1 + [(13 - mobile equipment load in amperes)/0.87], rounded to the nearest lower whole number. All other receptacles must be removed or disabled.

d. Since most commercial personal computers and peripherals, copiers, etc., generally do not disconnect both power lines when the power switch is in the ″off″ position, these mobile equipments should be unplugged from the receptacle after they are switched off in order to have them truly deenergized, unless it can be ascertained the on/off switch disconnects both power lines.

e. Computer power strips (surge suppressors) must be of the marine type. They must have a metal case, a double-pole switch/circuit breaker, and dual thermal fuses to prevent dangerous overheating. They must provide both common and normal mode protection and be listed by a nationally recognized testing laboratory such as Underwriters Laboratories (UL). These items are now described by a commercial item description, CID A-A-50622 which includes reference to UL Standard 1449. A six-receptacle unit with a six-foot cord is available under NSN 6150-01-362-7192.

f. The Electrical Safety Officer should keep an inventory of mobile equipment aboard ship and conduct periodic inspections on the ship's isolated receptacle circuits to assure compliance with a, b, c, and d above.

g. For submarines, mobile equipment should be connected to a separate single-phase circuit through an isolation transformer supplied from the non-vital bus if compliance with steps a through c above is not feasible.

300-2.7.3.5.1 A two-conductor flexible cable and two-prong plug may be used to power mobile equipment which has no exposed metal parts.

300-2.7.3.5.2 Mobile equipment which was originally supplied with a two-conductor power cord and is adequately grounded through direct contact with the mountings or by a separate ground connection between the chassis and the mountings may also use a two-conductor cable and plug. To determine if the mobile equipment is adequately grounded, less than 1 ohm dc resistance shall be measured between any exposed metal parts or the chassis and ship's hull.

300-2.7.3.5.3 Be sure to unplug all mobile equipment which is grounded by direct contact with mountings or by a ground connection to the mountings before moving the equipment. Otherwise, the equipment and its case may still be at dangerous potential and the equipment safety ground may be lost when the mounting hardware is removed or the ground conductor is disconnected.

300-2.7.3.5.4 Mobile equipment should be inspected before use aboard ship to verify that natural grounding of the equipment has not been eliminated by equipment modifications. For example, it was found that in one type of 8-1/2-inch bracket fan used on submarines and smaller surface ships, the fan motor case was insulated from the fan base by a vibration mount. All fans of this type should be provided with a stranded ground connection from the motor case to the mounting bracket. Another method of ensuring equipment grounding between the base and the attached electrical equipment consists of replacing the two-conductor cable from the base to the motor or electrical equipment with a three-conductor cable. Two of the conductors carry power to the motor or equipment; the third is connected to the motor or equipment case at one end and to the mounting bracket or base at the other end.

300-2.7.3.6 Approval of Portable Electrical Equipment. There is a great variety of portable tools and equipment on the market today. The Navy has adopted a policy to use commercially available tools and equipment when feasible. Shipboard 115-volt 60-Hz isolated receptacle circuits are ungrounded; both line conductors are above ground potential. The chassis in much of the electrical equipment designed for normal residential circuits ashore (in which one of the line conductors is ″neutral″) forms a part of the circuit. Exposed metal parts in this equipment can be energized when powered from the shipboard ungrounded system, creating a shock hazard to personnel touching them. Moreover, grounding the metal parts to the ship structure would place a ground on the 115-volt system, jeopardizing the continuity of power to other equipment. For these reasons, commercially available tools and personal equipment must not be used aboard ship unless it has been approved for shipboard use.

300-2.7.3.6.1 The Electrical or Electronic Officer or other designated personnel must inspect electrical equipment brought aboard ship for shipboard or personal use. The decision to accept or reject portable electrical and electronic equipment for use aboard ship, and the selection of interval between inspections, rests with the officer in charge of the inspecting shop.

300-2.7.3.6.2 Approved equipment shall be tagged or marked to indicate the approval. Two acceptable tagging methods are use of tag NSN-0116-LF-051-0025, which may be amended to indicate the interval between inspections; or use of color-coded tape or a self-adhering sticker.

300-2.7.3.6.3 Initial inspection and testing of electrical equipment shall be performed in accordance with the procedures of paragraph 300-2.7.5.1. These procedures shall also be followed to approve equipment for use following its repair. Routine inspections following initial inspection shall be performed according to the procedures of paragraph 300-2.7.5.2.

300-2.7.3.6.4 Personally-owned equipment/appliances such as portable radios, clock radios, electric shavers, curling irons, hair dryers, electric curlers, hobby equipment, etc. are not of standard issue. Personal equipment can be approved for shipboard use when the following conditions are met:

a. Adequate government-owned equipment is not available to meet the need.
b. The equipment has been inspected by the electrical/electronic shop and passes inspection for safe, rugged construction and test requirements of paragraph 300-2.7.5.1. Any personal equipment which fails to pass this inspection and testing must be appropriately modified to meet these requirements or its use shall be forbidden aboard ship. Final acceptance or rejection is at the discretion of the officer in charge of the inspecting shop.

Approved personal equipment shall be tagged. The interval between inspections of personal equipment shall not exceed six months.

300-2.7.3.6.5 Personally-owned hobby equipment such as hand-held, motor-driven carving tools are frequently found to be of flimsy construction and unsafe for use aboard ship. Such equipment may be retained on board, subject to inspection. At any time that the hobby tool is damaged or is obviously defective (for example, molded housings, cords, plugs contain cracks or breaks; cord insulation breaks when bent sharply), the tool shall not be used until repaired and re-inspected.

300-2.7.3.6.6 Electronic equipment such as radios, clock radios, television receivers, recorders, musical instruments, and amplifiers that do not meet the requirements of paragraphs 300-2.7.3.3, 300-2.7.3.4 or 300-2.7.3.5 shall have a built-in power transformer that completely isolates the primary or line side of the transformer from the secondary or equipment side. The isolation of the primary and secondary sides of the transformer must be checked by measuring the insulation resistance from each line terminal of the transformer to the chassis and exposed metal parts of the equipment. If the insulation resistance is greater than one megohm, the transformer is satisfactory. If the equipment does not have a power transformer, an isolation transformer must be installed (at owner's expense). The equipment shall be provided with a three-prong grounded plug and suitable cord. The power conductors of the cord shall be connected to the primary of the built-in or added isolation transformer. The grounding conductor of the cord shall be connected to the chassis and any exposed metal parts of the equipment at one end and to the ground prong of the plug at the other end. Some electronic devices have filters connected from the primary windings of the power transformers to ground. These filters are permitted when their dc resistance exceeds 500,000 ohms and the filter capacitor is no larger than 0.1 microfarad.

300-2.7.3.6.7 Electrical equipment such as flatirons, coffee pots, hand-held hair dryers, electric typewriters, sewing machines, vibrator massagers, dry cell battery chargers, and hobby equipment shall meet the provisions of paragraphs 300-2.7.3.1 through 300-2.7.3.5.4 and shall be provided with a portable cable in conformance with the requirements of paragraph 300-2.7.4 through 300-2.7.4.3.

300-2.7.3.6.8 Electric shavers and barber shears should have a completely insulating housing and isolated cutting blades for safe use onboard ship. The housing and cord must be free of cracks.

300-2.7.3.6.9 Personally owned or non-Navy-standard equipment such as fans, portable extension cords, high-intensity lamps, reading lamps, electric blankets, heating pads, electric power driven tools (except those specifically used as hobby tools), heat/sun lamps, hot plates and griddles, electric clocks, microwave ovens, portable extension lights, electric heaters, portable refrigerators, portable air conditioners, and immersion-type water heaters are prohibited from being introduced and used onboard ship. Adequate government-owned equipment is provided to meet the needs associated with these items. Non-Navy-standard items of the types mentioned are generally a shock hazard because of inferior insulation, leakage currents, and flimsy structure. Periodic inspections should be made to eliminate them from the ship.

300-2.7.4 PORTABLE CABLES. Portable cable is the electrical cable attached to a portable electrical device. Portable cables should be of the proper length and cross-sectional area. **Spliced portable cables should not be used** . Always support portable cables above decks, floor plates, and gratings. Never place them where they can be damaged by falling objects, by being walked on, or by contact with sharp corners or projections in the ship's hull or other objects. Where portable cables are passed through doorways or hatches, stops should be provided to protect the cables from being pinched or damaged by a door or hatch cover.

300-2.7.4.1 Grounding Conductor and Grounded Plug. Some portable tools in use on naval ships may not yet be provided with the grounded-type plug. In addition, there is a wide range of miscellaneous portable electric equipment that may be issued without being provided with a cord that has a grounding conductor and a grounded plug. This equipment includes galley equipment (fruit juice extractors, food-mixing machines, coffee pots, toasters); office equipment (adding machines, addressograph machines); shop equipment (key duplicating machines, valve grinders, mica undercutters, hot plates); medical equipment (infrared lamps, ultraviolet lamps, sterilizers); barber shop equipment (hair clippers); laundry equipment (flatirons); and others. Subject to the exceptions noted in paragraphs 300-2.7.3.3, 300-2.7.3.4, 300-2.7.3.5.1, and 300-2.7.3.5.2 (with respect to no exposed metal or grounding through Mounting), the following instructions shall be implemented.

300-2.7.4.1.1 All 115-volt or 230-volt, single-phase ac, and all 115-volt or 230-volt two-wire dc operated equipment onboard ship, that does not have a portable cable with a grounding conductor and grounded plug, and all such equipment subsequently issued to the ship without a cord that has a grounding conductor and grounded plug, should be provided with a three-conductor, flexible portable cable with grounded plug. The three-conductor, flexible cable should be type SO or ST, color-coded black, white, and green, as listed in the Federal Stock Catalog, Class 6145. The use of a grounding conductor integral to the equipment power cord is the only acceptable method of grounding. For general use, the plug should be bladed-type with U-shaped grounding prong. These are stocked for small and large diameter cords. Plugs that can be made watertight when in use are identified by symbol number 1218.3, NSN 5935-00-220-2213.

300-2.7.4.1.2 All 115-volt 3-phase electrically operated portable electrical equipment onboard ship or subsequently issued, which does not have a cord with a grounding conductor and grounded plug, should be provided with a type FHOF four-conductor flexible cable, color-coded black, white, red, and green, with Navy grounded plug, according to MIL-C-2726.

300-2.7.4.1.3 Replacement cable should be type SO or ST for three-conductor cords, and type FHOF for four-conductor cords. The green conductor shall be used for the grounding conductor. The plugs for three-conductor and four-conductor flexible cable are provided with a gland nut and packing that grips the cord securely and should prevent the cord from being pulled out of the plug under most conditions of rough usage. The connections to the cord on each portable tool or equipment repaired onboard or delivered to the ship should be examined for compliance with the preceding requirements and paragraph 300-2.7.4.2 before the equipment is used. The tests on the individual devices prescribed in paragraph 300-2.7.5.1 may not reveal these defects.

300-2.7.4.2 Connecting Portable Cable to Plug. In connecting the portable cable and plug, the following requirements shall be observed when connections are installed in portable equipment, extension cords, portable receptacles, and plugs.

a. Cord conductors must terminate in a standard crimp or solder type wiring terminal. If the standard terminal is impractical, all strands of each conductor must be twisted tightly together and formed into an eyelet (or a hook where the terminal screw is not removable), and dipped in or coated with solder to hold all strands tight.

b. The ground conductor of the portable cable shall be connected to the ground contact of the plug at one end, and to the metal casing of the portable equipment at the other. Extreme care must be exercised to see that the ground connection is made correctly. If the ground conductor which is connected to the metallic equipment casing is inadvertently connected to a line contact of the plug, a dangerous potential will be placed on the equipment casing. This will almost certainly cause a fatal shock to the person handling the portable equipment when it is plugged into a power receptacle, since line voltage will be on the exposed parts of the portable, metal-cased equipment. To guard against this danger, connections should be tested (as described in paragraph 300-2.7.5.1) after they have been made.

c. Portable cable conductors must be fastened securely to the terminals of the plug, tool, or extension receptacle. There must be no loose conducting strands which might make accidental electrical contact with metal parts they might touch.

d. Connections to all cords shall be examined to make sure that they comply with the foregoing. The testing procedure of paragraph 300-2.7.5.1 does not replace the physical checking of these requirements. Nonconforming portable electrical equipment must be taken out of service until corrected. It is not intended that molded rubber plugs and receptacles (in which the connections are encapsulated) be cut open for examination of connections.

e. Following the proper connection of the cable to the plug, the test procedure of paragraph 300-2.7.5.1 is required to ensure the plug connections are correct.

300-2.7.4.3 Length of Portable Cable. The length of the portable cable for portable tools should generally not exceed 25 feet, except that longer cords supplied as part of equipment need not be shortened. However, where use of the equipment aboard ship would frequently require a longer portable cable (or extension cord), a cable of up to 100 feet may be installed provided the conductors are of adequate cross-section to avoid excessive voltage drop in the portable cable. The length of the portable cable for such high-current equipment as heaters should be only as long as required.

300-2.7.4.4 Extension Cord and Plugs for Portable Electrical Equipment. Extension cord and plugs used to supply 115-volt 60-Hz single-phase power to portable electrical equipment, test equipment, power tools, and appliances must have a safety ground conductor when used aboard Navy vessels.

300-2.7.4.4.1 Because a metal hull ship is a hazardous location, personnel who must use portable electric tools and devices connected to extension cords should take the time to plug the portable tool or device into the extension cord before the extension cord is inserted into an energized bulkhead receptacle. Likewise, the extension cord should be unplugged from the bulkhead receptacle before the portable electrical tool or device is unplugged from the extension cord. Only approved extension cords shall be used. Authorized for inclusion in the ship's allowance are 25-foot extension cords and three outlet, 25-foot extension cords for use with portable tools and equipment. For use on flight, hangar and well decks, and floating drydock basins, 100-foot extension cords are authorized. Additionally, 100-foot extension cords, labeled **For Emergency Use Only** , are authorized for placement in damage control lockers. These extension cords may be manufactured using three conductor flexible cable (12/3), type SO or ST as listed in the Federal Stock Catalog, Class 6145, and attaching a grounding plug (NSN 5935-01-005-3579) to one end and a grounding receptacle (NSN 5935-01-012-3066) to the other end. Commercially available, UL approved equivalent items may be used. Commercially available, UL approved 25 and 100 foot extension cords with 12/3 wire may also be used. Cords shall be tested in accordance with paragraph 300-2.7.5.1.

300-2.7.5 TESTING AND INSPECTION OF PORTABLE EQUIPMENT. Test and inspection of portable equipment consists of:

a. Initial testing and inspection of new, repaired, or modified equipment.

b. Periodic testing and inspection to verify integrity of the enclosure, insulation and ground conductor continuity.

c . Routine inspection prior to issue of equipment. Any testing other than visual inspection shall be performed in a workshop equipped with a non-conducting-surface work bench and insulating rubber deck covering.

300-2.7.5.1 Testing and Inspection of New, Repaired, or Modified Portable Equipment. Before a new or repaired portable equipment is issued or used for the first time, it must be tested and approved, according to the following procedures:

1. Visually inspect the equipment to determine if it is stamped ″double insulated,″ is metal-cased, or is in a non-conducting case which does not require a safety ground (as defined in paragraph 300-2.7.3.4). Inspect plug to verify that equipment grounding conductor is provided for equipment requiring an equipment ground.
2. **Plugs with metal shells are prohibited aboard ship** . Portable electrical equipment supplied with a metal shell plug shall be modified to use a grounding plug having stock number NSN 5935-01-005-3579.
3. Examine the plug to determine that:

   a Plug is clean.

b Insulation and contacts are in good condition.

c All conductors are properly secured under terminal screws.

d All contacts are free of hangover fringes of molding material that would prevent good contact. Particular attention shall be given to the ground contact. It is not intended that molded rubber plugs or receptacles (in which the connections are encapsulated) be cut open for examination of connections.

4. Using a megger or insulation resistance measuring instrument, test the resistance from each of the blade prongs of the plug to the safety ground prong (if provided) and to any exposed metal parts. Measure the resistance with the ON/OFF switch of the portable equipment in both positions. Resistance less than 1 megohm indicates possible incorrect wiring or insulation damage within the plug, cable, or equipment. The equipment should not be used until the cause of the low insulation resistance is located and corrected.

5. If an equipment safety ground is provided, use ohmmeter to test resistance from the metal case and any exposed metal parts to the ground prong of the plug. If the resistance measured is greater than 1 ohm, the ground connections must be checked and properly secured. Move the portable cable, working it with a bending or twisting motion. A change in the resistance indicates broken strands in the grounding conductor. If a change in resistance is noticed, the cable must be replaced. If replacing the cord does not reduce the resistance between the metal enclosure or exposed metal parts and the ground prong below 1 ohm, the equipment shall not be used.

6. Reinforcement of the portable cable junction with the portable equipment usually consists of a molded rubber sleeve. Examine to insure that this sleeve is sound and free of cracks. Reinforcement consisting of coiled metal springs could be dangerous since it can conceal broken cable insulation and exposed conductors. Replacement of these springs is not required since replacement may not be practical and may do more harm than good. However, these springs should be included in the check of exposed metal parts during testing to insure that springs are insulated from the energized conductors in the cord.

300-2.7.5.2 Periodic Testing and Inspection of Portable Equipment. Portable electric equipment shall be tested periodically in accordance with procedures listed in paragraph 300-2.7.5.1. Portable equipment that gives an ohmmeter reading through the grounding circuit higher than 1 ohm or an insulation resistance measurement of less than 1 megohm shall not be used until the equipment is repaired.

NOTE

Where PMS is required, tests should be conducted in accordance with the applicable Maintenance Requirement Cards (MRCs).

300-2.7.5.2.1 The interval between inspections for portable equipment is at the discretion of the officer in charge of the inspecting shop, but should be no longer than the following:

a. Portable electrical tools/devices shall be tested at least quarterly.

b. Electrical equipment with flexible portable cable, such as hot plates, coffee makers, toasters, and portable (115-volt) vent sets, shall be tested at least quarterly.

c. Frequently touched, permanently mounted electrical equipment, such as bulkhead-mounted (115-volt) fans energized from receptacles, shall be tested at least once a year.

d. Personally-owned equipment/appliances shall be tested at least every 6 months.

300-2.7.5.3 Routine Inspection Prior to Issue of Portable Equipment. Prior to issuance of any portable electrical equipment, the equipment should be visually inspected as follows:

1. Examine enclosure for cracks or damage which might compromise safe use. Do not use equipment with a cracked or damaged enclosure.
2. Examine the attached cable and plug (including extension cords, when used) for tears, chafing, exposed insulated conductors, bent prongs, or damaged plug. Replace damaged cable or plug and test according to the procedures of paragraph 300-2.7.5.1 before using equipment.
3. Check wiring terminals and connections of the plug. Loose connections and frayed wires on the plug must be corrected and all foreign matter caught inside plug removed before the equipment is inserted into a receptacle.
4. Check for splices in the cable. **Spliced portable cables are extremely dangerous and shall not be used.** Replace cable and test according to the procedures of paragraph 300-2.7.5.1 before issuing or using equipment.

300-2.7.5.4 Testing Extension Cords. Extension cords, 25- and 100-foot MS-18053 single-, 3-, and 6-outlet (MIL-R-2726/69) shall be tested in accordance with the procedures listed for cables and plugs in paragraphs 300-2.7.5.1 through 300-2.7.5.3 and procedures for receptacles listed in paragraph 300-2.7.6.

300-2.7.6 TESTING GROUNDED RECEPTACLES. A test of any newly installed, repaired, or modified receptacle shall be made in accordance with paragraph 300-2.7.6.1 to verify that all connections have been properly made. In addition, periodic inspections shall be made in accordance with paragraph 300-2.7.6.2 to ensure a low resistance from the receptacle safety ground connection to the ship's hull.

300-2.7.6.1 Testing Receptacle Connections (New Installation). A test shall be made at the time a grounded receptacle has been installed, repaired, or modified in any way to determine whether the connections are correct. Thereafter, the test shall be repeated only following an overhaul or other period during which the receptacle may have been deranged, rewired, etc. This test shall be made as follows:

1. Deenergize circuit, test to make sure that the receptacle is deenergized.
2. Remove receptacle box cover and examine for the following:
   a Correct wiring
   b Secure terminal screws
   c Clean ground contact
3. For single-outlet bladed receptacles (used in light fixtures) and double-outlet receptacles, examine for the following:
   a Correct receptacle type having two parallel slots and one U-shaped ground hole.
   b Corrosion protection caps authorized for use in crew heads and showers.
4. Using an ohmmeter, test resistance from ship's hull to face of ground contact (must be less than 1 ohm).
5. Replace receptacle box cover.
6. Insert grounded plug attached to a metal-cased equipment into the receptacle. Using an ohmmeter, test resistance from the equipment housing to ship's hull. This resistance must be less than 1 ohm. If greater than 1 ohm, repair connections or replace receptacle and repeat entire test.

300-2.7.6.2 Periodic Test of Grounded Receptacles. Each grounded receptacle on a ship shall periodically undergo a ground continuity test to ascertain that vibration, corrosion, or some other cause has not degraded the receptacle ground connection. This test shall be performed every 6 months for each installed receptacle that is exposed to the weather and annually for all others. The following procedure shall be used to perform the ground continuity test:

1. Plug any small 115-volt portable electric tool that has a metal housing, a portable cable with equipment safety ground, and has been tested to be satisfactory into the receptacle to be tested. The switch on the tool should be left in the OFF position.
2. Secure one ohmmeter lead to the metal housing of the tool and the other lead to the ship's hull. The ohmmeter reading must be less than 1 ohm to indicate a satisfactory grounding connection from the equipment housing through the plug and receptacle to the ship's hull.
3. A plug that mates to the receptacle to be tested may be used as an alternative to the metal-cased tool. The power prongs of this plug are to be left unconnected. Connect one test lead of an ohmmeter to the ground terminal of the plug. Connect the other test lead of the ohmmeter to ship's hull. Insert the plug into the receptacle to be tested. The resulting reading must be less than 1 ohm.
4. Where the receptacle contains more than one outlet, the test procedures shall be repeated for each outlet.

300-2.8 PRECAUTIONS FOR MEDICAL SPACES

300-2.8.1 MEDICAL SPACES. Power is supplied from isolated receptacle circuits energized from the emergency lighting system for receptacles, switches, receptacles for surgical lights, and relay lanterns in Medical Spaces. These receptacles are for medical user equipment only.

300-2.8.2 ELECTRICALLY SUSCEPTIBLE PATIENT (ESP) LOCATIONS. Operating rooms, surgical dressing rooms and intensive care quiet rooms are designated as electrically susceptible patient (ESP) locations having unique patient care electrical safety requirements. The principal safety concerns are to minimize the leakage current available that could pass through a patient's body and to maintain power continuity to medical equipment that may be supporting the life of the patient.

300-2.8.3 ISOLATION TRANSFORMERS. Each ESP space is supplied power from a 5-kVA hospital isolation transformer which provides 115-volt 60-Hz power for its associated space other than that for general area lighting and portable X-ray machine. No other user equipment is to be supplied from these transformers.

300-2.8.4 ISOLATED RECEPTACLES. Isolated receptacles are provided to supply power from the isolation transformers to equipment used in ESP locations. The receptacles are 115-volt 60-Hz single-phase for medical equipment use only.

300-2.8.5 LINE ISOLATION MONITORS. Line isolation monitors are installed to monitor the total (resistive and capacitive) leakage current of the secondary circuit of the ESP isolation transformer.

300-2.8.6 CIRCUIT BREAKER DISTRIBUTION PANEL. A circuit breaker distribution panel is provided for each hospital isolation transformer. Two receptacles are connected to a circuit breaker and each circuit breaker interrupts both lines of its circuit to eliminate any possible source of leakage current to ground (ship's structure).

300-2.8.7 EQUI-POTENTIAL REFERENCE. Each ESP has an Equi-Potential Reference (EPR) Ground Bus. The enclosures of all fixed electrical equipment, including power panel enclosure and the grounding pole of each receptacle within the ESP space are connected to the EPR Ground Bus. Piping, piping drains, cable armor and other permanently installed metallic equipment that may conduct unwanted potentials into the EPR space are bonded at the point of entry and the point of departure to the EPR Ground Bus. Operating tables and portable nonelectrical equipments, such as carts, chairs and bed pans, shall not be intentionally connected to the EPR Ground Bus. Fixed nonelectrical equipment such as beds, sinks, stands, tables, and towel racks shall not intentionally be grounded. However, grounding that otherwise results from normal installation methods is permitted. Bulkheads, especially each panel of metal joiner bulkheads and deck of the ESP space are connected to EPR Ground Bus.

300-2.8.8 GROUND RECEPTACLE BOX. Special ground receptacle boxes are provided in each ESP space in the immediate vicinity of each power receptacle or group of receptacles. Each special ground receptacle box contains a minimum of four but no less that one for each outlet of the adjacent power receptacles. Terminals of each receptacle shall be connected with a single copper bus. Each special grounding receptacle enclosure contains at least one welded stud to permit connecting the enclosure to the bus. This stud may be used for an attachment point when connecting the special ground receptacle to the EPR Ground Bus. Equipment that requires grounding may be connected to the copper bus in the special grounding receptacles in lieu of the EPR Ground Bus.

300-2.8.9 GROUNDING CONDUCTORS. Grounding conductors shall be stranded and have a minimum cross sectional area of 9000 circular mils (AWG #10). Each end of the conductors shall have a washer type lug crimped and soldered to it. The resistance between the EPR Ground Bus and each metallic item that requires grounding, including the power receptacle grounding pole, shall not exceed 0.05 ohms. All grounding connections shall use nuts in accordance with MIL-N-25027, **Nut, Self-locking, 250° F, 450° F, 800° F,** and a lock washer.

300-2.8.10 GROUNDING CABLE ASSEMBLIES. Portable grounding cable assemblies are provided for use with the EPR systems. Cables are stored near the intensive care areas. Each cable assembly consists of a 15-foot minimum length of #10 AWG single conductor cable with a plug connector soldered to one end and an alligator clip crimped (or screwed) and soldered to the opposite end. The alligator clips shall have a finish suitable for use in medical spaces (sterile conditions) with jaws at least 5/8 inch wide which when fully opened will have a minimum opening of 5/8 inches. The alligator clip shall provide a means of strain relief for the cable at the point of attachment. Jaw closing force shall be sufficient to ensure penetration of paint or enclosure finish of electrical equipment which may be used in ESP locations.

300-2.8.11 ELECTRICAL CORDS AND PLUGS. All electrical power cords for medical equipment (except for surgical lights and relay-controlled hand lanterns) to be connected to the ESP power circuits are to be fitted with NAVSEA approved plug connectors.

300-2.8.12 POWER CONDUCTOR TO GROUND IMPEDANCE. The impedance (capacitive and resistive) to ground of either conductor of the ESP power system shall exceed 1 megohm at both dc and operating frequency.

300-2.8.13 LABEL PLATES. A label plate shall be installed at each receptacle or group of receptacles in each ESP space stating: **″DO NOT USE FOR NON-MEDICAL EQUIPMENT.″** A label plate is required in each ESP space power distribution panel stating: **″DO NOT CONNECT ANY RECEPTACLES OR EQUIPMENTS TO THIS PANEL THAT ARE NOT IN THIS (name of space).″**

300-2.8.14 RECEPTACLE FOR PORTABLE X-RAY MACHINES. A receptacle that is compatible with the plug connector for the portable X-ray machine is installed in the Operating Room, Surgical Dressing Room, Intensive Care Quiet Room and Ward. The receptacle shall be connected to an ungrounded source of 115-volt 60-Hz capable of 30 amps service. In those spaces containing an EPR Ground Bus, the grounding pole of the receptacle shall be connected to the EPR with a conductor equal to or larger than those in the X-ray machine power cord. However, the conductor shall not be smaller than 9000 circular mils. In those spaces which do not have an EPR Ground Bus, the grounding pole shall be securely bonded to the ship's hull with a single conductor with the above sizing requirements. A label shall be installed immediately adjacent to each portable X-ray receptacle stating:

115 VOLT 60-HZ FOR PORTABLE X-RAY MACHINE ONLY DO NOT USE FOR OTHER MEDICAL EQUIPMENT .

300-2.9 RESUSCITATION FOR ELECTRIC SHOCK

300-2.9.1 SOURCE OF INSTRUCTIONS. The following instructions on resuscitation were provided by the Naval Medical Command.

300-2.9.2 RESUSCITATION. Resuscitation after electric shock includes artificial respiration to re-establish breathing and external heart massage to re-establish heartbeat and blood circulation.

a. If the person shows no sign of breathing, immediately apply mouth-to-mouth artificial respiration after removing the victim from contact with the electricity.

b. If there is no pulse, apply heart massage immediately. Do not waste precious seconds carrying the victim from a cramped, wet, or isolated location to a roomier, drier location.

c. If desired, breathe into victim's mouth through a cloth or a handkerchief placed over the victim's face. If assistance is available, take turns breathing into victim and massaging the heart.

300-2.9.3 CARDIAC ARREST (LOSS OF HEARTBEAT). If the victim has suffered an electric shock and has no heartbeat, a cardiac arrest will result. This can be demonstrated by finding a complete absence of any pulse at the wrist or in the neck. Associated with this, the pupils of the eyes will be very dilated, and respiration will be weak or stopped. The victim may appear to be dead. Under these circumstances severe brain damage will occur in 4 minutes unless circulation is re-established by cardiac massage.

300-2.9.4 CARDIOPULMONARY RESUSCITATION. Basic CPR is a simple procedure after the victim has been removed from the shock hazard. It is as simple as A-B-C: Airway, Breathing, and Circulation.

1. If you find a collapsed person, determine if victim is conscious by shaking the shoulder and shouting, ″Are you all right?″ If no response, shout for help. Then open the airway (see Figure 300-2-7, view A). If victim is not lying flat on the back, roll victim over, moving the entire body at one time as a total unit.
   a To open the victim's airway, use the head tilt/chin lift method. Kneel beside the victim's shoulder; lift the chin up gently with one hand while pushing down on the forehead with the other to tilt the head back. The chin should be lifted so the teeth are brought almost together. Avoid completely closing the mouth. Once the airway is open, place your ear close to the victim's mouth:
      (1) Look at the chest and stomach for movement.

(2) Listen for sounds of breathing.

(3) Feel for breath on your cheek.

b If none of these signs is present, victim is not breathing. If opening the airway does not cause the victim to begin to breathe spontaneously, you must provide rescue breathing.

2. The best way to provide rescue breathing is by using the mouth-to-mouth technique.

a Take your hand that is on the victim's forehead and turn it so that you can pinch the victim's nose shut while keeping the heel of the hand in place to maintain head tilt (see Figure 300-2-7, view B).

b Open your mouth wide, take a deep breath, and make a tight seal over the victim's mouth. Breathe into victim's mouth two times with complete refilling of your lungs after each breath. Watch for victim's chest to rise. Rescue breaths are to be given at the rate of 1 to 1-1/2 seconds each, allowing the lungs to deflate between breaths.

3. After giving two full breaths (1 to 1-1/2 seconds each), locate the victim's carotid pulse to see if the heart is beating.

a To find the carotid artery, locate the voice box. Slide the tips of your index and middle fingers into the groove beside the voice box. Feel for the pulse. Cardiac arrest can be recognized by absent breathing and an absent pulse in the carotid artery in the neck (see Figure 300-2-7, view C).

b If you cannot find the pulse, you shall provide artificial circulation in addition to rescue breathing. **Activate the Emergency Medical Services System (EMSS). Send someone to call 911 or your local emergency number.**

4. Artificial circulation is provided by external cardiac compression. In effect, when you apply rhythmic pressure on the lower half of the victim's breastbone, you are forcing the heart to pump blood.

a To perform external cardiac compression properly, kneel at the victim's side near the chest. Locate the notch at the lowest portion of the sternum. Place the heel of one hand on the sternum 1-1/2 to 2 inches above the notch. Place your other hand on top of the one that is in position. Be sure to keep your fingers off the chest wall. You may find it easier to do this if you interlock your fingers (see Figure 300-2-7, view D).

b Bring your shoulders directly over the victim's sternum as you compress downward, keeping your arms straight. Depress the sternum about 1-1/2 to 2 inches for an adult victim. Then relax pressure on the sternum completely. However, do not remove your hands from the victim's sternum, but do allow the chest to return to its normal position between compressions. Relaxation and compression should be of equal duration.

c If you are the only rescuer, you must provide both rescue breathing and cardiac compression. The proper ratio is 15 chest compressions to 2 full breaths. You must compress at the rate of 80 to 100 times per minute when you are working alone since you will stop compressions when you take time to breathe.

d When there is another rescuer to help you, position yourselves on opposite sides of the victim if possible. One of you should be responsible for interposing a breath during the relaxation after each fifth compression. The other rescuer, who compresses the chest, should use a rate of 60 compressions per minute (Table 300-2-2).

Table 300-2-2 RATE OF COMPRESSION

Rescuers	Ratio of Compressions to Breaths	Rate of Compressions
ONE	15:2	80 times/min.
TWO	5:1	60 times/min.

e If you suspect the victim has suffered a neck injury, you must not open the airway in the usual manner. If the victim is injured in a diving or vehicle accident, you should consider the possibility of such a neck injury. In these cases, the airway should be opened by using a modified jaw thrust, keeping the victim's head in a fixed, neutral position (Figure 300-2-7, view E).

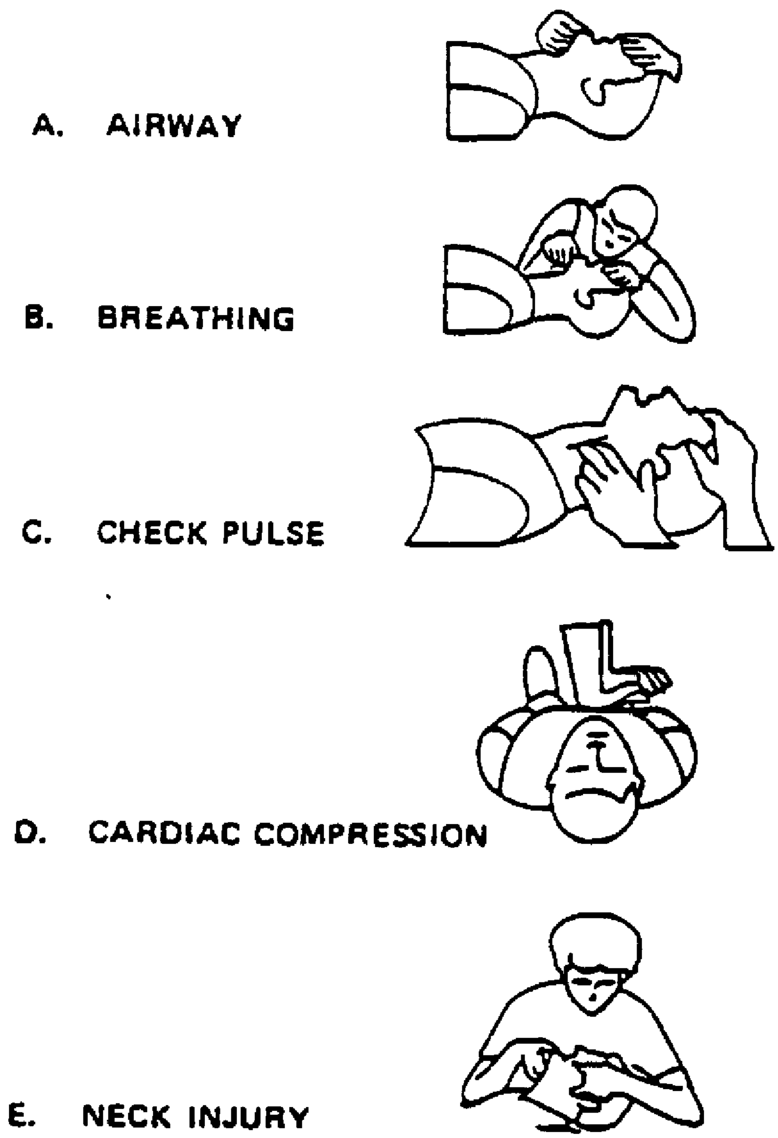


Figure 300-2-7 Cardiopulmonary Resuscitation

300-2.9.5 CPR SUMMARY. The following summary is given for a quick reminder:

1. Is the victim unconscious? Has the victim been removed from the electrical hazards?
2. If so, shout for help, open the airway, and check for breathing.
3. If no breathing, give two full breaths.
4. Check carotid pulse.
5. Send someone to get medical assistance.

6. If no pulse, begin external cardiac compression by depressing lower half of the sternum 1-1/2 to 2 inches.
7. Continue uninterrupted CPR until advanced life support is available.

300-2.9.5.1 CPR for One Rescuer. Give 15 compressions to 2 breaths at a rate of 80 compressions a minute (4 cycles per minute).

300-2.9.5.2 CPR for Two Rescuers. Give 5 compressions to 1 breath at a rate of 60 compressions a minute.

300-2.9.5.3 Practice Periodically. Periodic practice in CPR is essential to ensure a satisfactory level of proficiency. A life may depend upon how well you have remembered the proper steps of CPR and how to apply them.

SECTION 3.

ELECTRICAL INSULATION

300-3.1 INSULATING MATERIAL

300-3.1.1 INSULATION NEED. Insulation is needed on electric cables and equipments to isolate current-carrying conductors from electrically conductive structural parts. In addition, points of unequal potential on separate conductors must be insulated from each other. Normally the conductivity of the insulation should be sufficiently low to result in negligible current flow through or over the surface of the insulation. In support of the information contained in section 3, pertinent data concerning insulating materials carried in the Navy supply system is given in Appendix A - Electrical Insulating Materials Available for Repair of Electrical Equipment.

300-3.1.2 AIR SPACING. In order to use air as an insulation, a solid insulating material must be used for support to maintain the required air-spacing distance between uninsulated conductors. Such material must insulate against current which tends to flow through it as well as prevent excessive creepage along its surface. Creepage is defined as the conduction of electricity across the surface of a dielectric. Creepage distance is defined as the shortest distance between two conductors or between a conductor and ground, measured along the surface of the insulating material. By increasing the creepage distance, the creepage current is reduced. The air-spacing distance and creepage distance required depend upon the voltage involved, the degree of enclosure, the configuration of the conductors and insulation, and the nature of the insulation material supporting the conductors. Values of air-spacing (clearance) and creepage distances specified for Navy equipment are shown in Table 300-3-1.

300-3.1.3 INSULATION SYSTEM CLASSIFICATION. All insulating materials used within a given insulation system shall be compatible with each other and the operating environment. If compatibility is unknown (new material), the manufacturer shall provide the appropriate data or certify compatibility. Experience has shown that the life characteristics of insulation systems cannot be reliably inferred solely from the characteristics of the constituent materials. Instead, insulation systems are classified based on service experience or on an accepted test procedure that can demonstrate compatibility and adequate life expectancy. The classification process, whether by service experience or by test, exposes the insulation system to a combination of vibration, humidity, voltage and temperature. Insulation systems are classified by limiting temperature (thermal endurance) to provide an acceptable service life in the presence of the above elements.

300-3.1.3.1 New or Modified Insulation System. New or modified insulation systems may be evaluated by accepted test procedures and, when so evaluated, shall have equal or longer thermal endurance than a service-proven system of the same class at the prescribed test conditions (Underwriters Laboratories Std-UL 1446). A new or modified insulation system may also be classified in a higher class by test if it has equal or greater thermal endurance at appropriately higher test temperatures when compared to a service-proven system under the same test conditions.

300-3.1.3.2 Temperature Classification. Insulation systems are classified by temperature because temperature has the predominate effect on insulation life. Insulation systems are grouped into equivalent classes that are designated by letters, numbers or other symbols. Table 300-3-2 presents the classification for insulation systems used by the Navy based on limiting temperature.

300-3.1.4 OPERATING TEMPERATURE. The maximum allowable insulation temperature for electrical equipment is determined by the individual equipment specification in consideration of the limiting temperature of Table 300-3-2. The maximum temperature set by the equipment specification is less than or equal to the limiting temperature of the equipment's insulation system class. Operating temperatures that produce actual burning or charring may destroy insulation in a few seconds. Temperatures slightly in excess of specification limits will produce gradual deterioration that is not immediately apparent, but will shorten the life of the insulation system. It is therefore important to maintain electrical equipment operating temperatures within specification limits. As a rule of thumb, insulation life will decrease by one half, due to thermal aging, for every 10 to 15° C above the specification limit.

300-3.1.5 TEMPERATURE RISE. The maximum allowable insulation temperature, indicated in the equipment specification, is comprised of the maximum allowable temperature rise in the winding's insulation, or conductors and the design maximum ambient temperature that the equipment will be exposed to. The temperature of the insulation and the conductors is considered identical. The temperature rise is the increase in winding (insulation/conductor) temperature, above ambient, due to heat producing losses in the equipment. Measurement of equipment's temperature rise can be used to verify acceptable operation at rated conditions. The equipment's measured temperature rise at rated load and voltage is often shown on the equipment drawings in the technical manual. The design maximum ambient temperature is usually indicated on the equipment's nameplate and in the technical manual. With the exception of non-propulsion motors, in the absence of measured temperature rise data, Table 300-3-3 may be used as guidance for verifying compliance with temperature rise limits. The maximum acceptable temperature rise for non-propulsion plant motors, measured by the Resistance Method (see 300-3.1.6.2), is determined as follows:

Class B or F insulation systems: Maximum temperature rise = 120°C - (nameplate maximum ambient)

Class 11 insulation systems: Maximum temperature rise = 145°C - (nameplate maximum ambient)

Class N insulation systems: Maximum temperature rise = 170°C - (nameplate maximum ambient)

Table 300-3-1 ELECTRICAL CREEPAGE AND CLEARANCE DISTANCE

			Creepage (in)[4]	
Voltage (rms) ac or dc	**Set[1]**	**Clearance (in)**	**Open[2]**	**Enclosed[3]**
Up to 64	A	0.063	0.063	0.063
	B	0.125	0.125	0.125
	C	0.125	0.375	0.500
64-150	A	0.063	0.063	0.063
	B	0.125	0.250	0.125
	C	0.250	0.750	0.375

Table 300-3-1 ELECTRICAL CREEPAGE AND CLEARANCE DISTANCE

- Continued

			Creepage (in)[4]	
Voltage (rms) ac or dc	**Set[1]**	**Clearance (in)**	**Open[2]**	**Enclosed[3]**
150-300	A	0.063	0.063	0.063
	B	0.125	0.250	0.125
	C	0.250	0.750	0.500
300-600	A	0.063	0.125	0.125
	B	0.125	0.250	0.250
	C	0.250	0.750	0.500
600-1000	A	0.125	0.500	0.375
	B	0.250	1.000	0.750
	C	0.500	2.000	1.500
1000-3000	C	2.000	4.000	2.000
3000-5000	C	3.000	5.000	3.000

NOTES:
1. Set A - Normal operating volt-ampere rating up to 50.
Set B - Normal operating volt-ampere rating up to 2000.
Set C - Normal operating volt-ampere rating over 2000.
2. Open. Equipment or parts with open enclosures as defined in MIL-STD-108, Definitions of and Basic Requirements for Electric and Electronic Equipment.
3. Enclosed. Equipment or parts with enclosures other than open, as defined in MIL-STD-108, Definitions of and Basic Requirements for Electric and Electronic Equipment.
4. For top-curved surfaces having a radius greater then 3 inches and for top-flat surfaces, surface creepage distance shall be increased 33% where these surfaces have irregularities which permit the accumulation of dust and moisture.
5. Use of electrical parts or assemblies (potentiometers, connectors, printed wiring assemblies, and so forth) having lesser creepage and clearance distances is permissible provided the parts and assemblies conform with applicable military specifications, and their energized portions are hermetically sealed.

Table 300-3-2 LIMITING TEMPERATURES OF INSULATION SYSTEMS

Limiting Temperature (°C)	Insulation System Letter Class	Insulation System Number Class
105	A	105
130	B	130
155	F	155
180	H	180
200	N	200
220	R	220
240	S	240

300-3.1.6 TEMPERATURE MEASUREMENT METHODS. The following methods are used to measure operating temperature and temperature rise of electrical machines, instruments, and apparatus. All measurements shall be made after normal equipment operating temperatures are achieved. See ANSI/IEEE STD 1-1986, IEEE STD 119-1974, and IEC 505-1975 for a detailed discussion of these and other methods.

300-3.1.6.1 Method 1 - Thermometer Method. This method consists of the determination of temperature by resistance thermometers, alcohol thermometers, or by surface and contact thermocouples where any of these instruments are applied to the hottest accessible part of the equipment. **Mercury thermometers shall not be used.** This method is preferred for uninsulated windings, exposed metal parts, gases, and liquids. It is also preferred for surface measurements generally and whenever other methods are not applicable or practical as in the case of some windings with very low resistance. Thermocouples are preferred for measuring rapidly changing surface temperatures as in the case of resistors, commutators, collector rings, and other parts of rotating equipment. The number of thermometers or thermocouples used shall be liberal and shall be so disposed as to ascertain the highest temperature. The thermometer bulbs or thermocouples contact points shall be placed in such positions that they make the maximum practicable contact with the part whose temperature is to be measured, and shall be so firmly supported that this degree of contact will not be altered by gravity and vibration. The bulbs of thermometers shall be surrounded by a small amount of oil putty or equivalent to help maintain contact. The probes of contact thermocouples shall be sufficiently sharp to penetrate any oxide film present on the metal surface being measured.

300-3.1.6.2 Method 2 - Resistance Method. This method consists of the determination of temperature by comparison of the resistance of a winding at the temperature to be determined, with the resistance at a known temperature. This method is preferred for insulated windings, except where measurements cannot be accurately made due to uncontrollable resistance in contacts, or where it is impractical to make connections to obtain measurements before an undesirable drop in temperature occurs. For resistance less than 1 ohm a high accuracy instrument, such as a Kelvin bridge shall be used. In the application of this method, accuracy is essential in the measurement of all resistance and of the temperature of the windings at which the cold resistance is measured. Care shall be taken not to include any unnecessary external resistances. The following formula shall be used in computing temperature rise of copper conductors by the resistance method:

Table 300-3-3 MAXIMUM PERMISSIBLE TEMPERATURE RISE (°C)

	Insulation Class									
	40°C Ambient			**50°C Ambient**			**65°C Ambient**			**80°C Ambient**
Part	**B**	**F**	**H**	**B**	**F**	**H**	**B**	**F**	**H**	**H**
1. Windings other than those specified in 4										
a. Dripproof protected,	80	105	125	70	95	115	60	80	105	90
b. Totally enclosed fan cooled, spray-tight fan cooled, water-tight fan cooled, Method 2	85	110	135	75	100	125	65	85	110	95
c. Others, Method 2	85	110	135	75	100	125	65	85	110	95
2. Cores and mechanical parts in contact with or adjacent to the insulation										
a. Equipment under 1a, Method 1	70	95	115	60	85	105	45	70	90	75
b. Equipment under 1b and 1c, Method 1	75	100	125	65	90	115	50	75	100	85

Table 300-3-3 MAXIMUM PERMISSIBLE TEMPERATURE RISE (°C) -

Continued

	Insulation Class									
	40°C Ambient			**50°C Ambient**			**65°C Ambient**			**80°C Ambient**
Part	**B**	**F**	**H**	**B**	**F**	**H**	**B**	**F**	**H**	**H**
3. Collector rings										
a. If class B insulation is employed in or is adjacent	85	-	-	75	-	-	60	-	-	-
b. If class H or N insulation is employed	-	-	125	-	-	115	-	-	100	85
4. Bare copper windings and single-layer field windings with exposed uninsulated surfaces										
a. Equipment under 1a	80	105	130	70	95	120	55	80	105	90
b. Equipment under 1b and 1c	85	110	135	75	100	125	60	85	110	95

Temperature rise, C°

$$= (234.5 + t_c)\frac{R_h}{R_c} - (234.5 + t_a)$$

Where:

R_c = Cold resistance of winding

R_h = Hot resistance of winding

t_c = Temperature (°C) of winding when cold resistance was measured

t_a = Ambient temperature (°C) during the last quarter of the test

300-3.1.6.3 Method 3 - Infrared Method. The infrared method consists of a noncontact scanner that detects and measures the intensity of radiant energy in the infrared spectrum that is emitted by equipment. Heat is typically generated by the forces of friction, electrical resistance, or chemical reaction. Infrared imaging diagnostics can provide the following information about equipment material condition:

a. Remote indications of component true surface temperature

b. A relative measure of the difference between two different surface temperatures

c. Indications of hot spots by selected area readings. Infrared imaging diagnostics can provide evidence of abnormal conditions or potential failure by allowing comparison of the present reading with an established standard. This method can also be utilized to validate proper operation after repair and installation. All objects emit heat (i.e., infrared radiation) which is consistently being absorbed and re-emitted by everything in the surrounding environment. Thermography is the term used to describe the process of making this thermal radiation visible and able to be interpreted. Thermal radiation, the basis for infrared (IR) temperature measurement, is dependent on several factors which include temperature and surface emissivity. Surface emissivity is defined as the ratio of energy emitted from a surface to that energy emitted by a blackbody at the same temperature and wavelength. A blackbody which is a perfect radiator has an emissivity of 1.0. Objects such as oxidized metals have emissivities in the range of 0.5 to 0.9. Other materials such as polished aluminum have emissivities of about 0.1. For making IR measurements, the Type B Infrared Thermal Imaging System (IRTIS) as specified in Military Specification DOD-I-24698 (SH), **Infrared Thermal Imaging Systems,** shall be used on electrical and electronic equipment. Specific procedures for conducting thermal surveys can be found in DOD-STD-2194 (SH), **Infrared Thermal Survey Procedure for Electrical Equipment.** Operators shall be qualified in the use of infrared equipment. Infrared equipment (such as Thermalvision 870 from AGEMA at Danderoid, Sweden) may be found at shipyard facilities. The IR scanner should be placed as close as possible to the equipment or component being measured. Since measurements are made on normally operating and energized equipment, safety precautions shall be exercised.

CAUTION

The IRTIS test equipment operator shall not extend the scanner across the plane of open electrical panels or coverings.

300-3.1.7 FUNDAMENTAL PROPERTIES OF INSULATION. Two fundamental properties of insulation are insulation resistance and dielectric strength. These are entirely different and distinct properties of insulation and no simple relation between them has been found. However, extremely low values of insulation resistance, especially when measured values have decreased sharply or steadily over a period of time, should be taken as a warning that the dielectric strength may be low or may be decreasing to the point where the insulation will rupture at the service voltage.

300-3.1.7.1 Insulation Resistance. Insulation resistance is the resistance to current leakage through and over the surface of insulation. Insulation resistance can be measured without damaging the insulation and furnishes a highly useful guide for determining the general condition of insulation, but is not entirely conclusive by itself. Test measurements have shown that insulation resistance measurements at moderate voltages may actually increase after the insulation has been punctured by ac high potential. Clean, dry insulation having cracks or other faults may show a high value of insulation resistance but obviously is not suitable for use. These limitations of insulation resistance values must be fully realized when the condition of insulation is appraised by such values. For details on insulation resistance measurements and their significance see paragraphs 300-3.2 through 300-3.4.11.1.

300-3.1.7.2 Dielectric Strength. Dielectric strength is the ability to withstand potential difference and is usually expressed in terms of voltage at which the insulation fails due to electrostatic stress. Maximum dielectric strength values can be measured only by testing to destruction. See paragraphs 300-3.5.3 through paragraph 300-3.5.4.8.4 for further information on high potential tests. See **NSTM Chapter 430, Interior Communication Installations,** for information on high potential tests on interior communication systems.

300-3.2 INSULATION RESISTANCE MEASUREMENT

300-3.2.1 USE. Measurements of insulation resistance form an important part of any adequate program for the maintenance of electrical insulation. Measured values of insulation resistance:

a. Serve as a guide in determining when cleaning, drying, or overhaul is necessary to prevent further development of conditions that might lead to eventual insulation failure and loss of equipment from service.

b. Eliminate needless shutdown and overhaul to improve the insulation resistance of cables or machines on which the insulation is entirely adequate.

300-3.2.2 INSULATION RESISTANCE. When one terminal of a source of constant dc potential is connected to a conductor in a shipboard cable or a winding on a machine and the other terminal is connected to the metallic parts of the ship’s hull or to the machine, a current flows through the body of the insulation on the conductor, or over its surface, or both. When a large bare conductor area is exposed, as in dc armatures and in certain types of field windings, leakage over the surface of the insulation will be more pronounced than in other types of windings in which there is little or no exposed conductor. For all types of windings, however, any accumulation of dirt or moisture which forms a low resistance film on the surface of the insulation will increase the possible leakage paths to ground. This will increase the leakage current and decrease the insulation resistance, which is simply the impressed voltage divided by the total leakage current.

300-3.2.2.1 Parallel Resistance. The insulation resistance of two or more circuits connected together will be less than the insulation resistance of any one of the individual circuits. For example, suppose that the insulation resistance of the armature circuits of a dc generator and motor are 23 and 11 megohms, respectively, and the armature circuits are connected by two cable legs having insulation resistances of 7 and 9 megohms. The insulation resistances of the four component circuits are all connected in parallel between the combined circuit and ground. Hence, the insulation resistance of the combined circuit will be given by:

$$I/R = 1/23 + 1/11 + 1/7 + 1/9$$

$$R = 2.57 \text{ megohms}$$

300-3.2.2.1.1 The insulation resistance of the combined circuit is, therefore, materially less than the insulation resistance of any one of the component circuits. To find the insulation resistance of each component circuit it must be disconnected from the others and measured alone.

300-3.2.3 MEASURING INSTRUMENTS. All naval ships except small craft are allotted portable insulation resistance measuring instruments, usually of the hand-crank generator type. Such instruments should normally be utilized for shipboard maintenance test of insulation resistance on individual circuits or equipments. Instructions covering the proper operation of these instruments are included with the instrument.

300-3.2.4 DC VOLTMETER MEASUREMENT. When an insulation resistance measuring instrument is not available, a method of measuring insulation resistance which requires no special equipment is to employ a dc voltmeter having a resistance preferably higher than 60,000 ohms, and a steady dc power source of suitable voltage. Test the power source to see if either side has a zero or low resistance ground. This test is made by connecting the voltmeter between ground and one side of the supply circuit, then between ground and the other side. If both sides give a zero reading on the voltmeter or only a small reading, neither side of the line has a low resistance to ground. If one side gives a zero or very small reading while the other side gives full line voltage, the side which gives the zero reading has a low resistance ground. Connect the grounded side (or either side if neither has a low resistance ground) through a low capacity fuse to the metal structure of the machine. Connect the voltmeter between the other side of the line and the copper conductor in the winding whose insulation resistance is to be measured.

300-3.2.4.1 Measurement Response. When voltage is applied across the insulation, there will be an initial kick due to the charging current, followed by a gradual decrease in the pointer deflection to a steady value. The resistance of the insulation is then given by the formula:

$$R = r \frac{(E - V)}{V}$$

Where:

R = insulation resistance of the winding or circuit, in ohms

r = resistance of voltmeter, in ohms. The voltmeter resistance is usually given on the instrument; if not, it can be measured with aWheatstone bridge or by using a dc milliammeter to measure the current and dividing the voltmeter reading in volts by the current in amperes.

E = magnitude of test voltage

V = voltmeter deflection during test, in volts

300-3.2.4.2 Metering Effect. The resistance of the voltmeter has a direct bearing on the accuracy of the results. A voltmeter having a sensitivity of 100 ohms per volt will not permit measurements in excess of 2 megohms with any degree of accuracy for an applied voltage of 500 volts. The maximum resistance that can be measured with accuracy at voltages less than 500 volts is proportionately less. The maximum resistance that can be measured with voltmeters having a sensitivity higher than 100 ohms per volt increases in direct ratio to the sensitivity in ohms per volt. Care should always be exercised to restrict the applied voltage to a value commensurate with the condition of the insulation.

300-3.2.5 UNGROUNDED POWER SYSTEMS. Most electric power systems on naval ships are ungrounded. This means that there are no permanent, low resistance connections between the power system and the structure of the ship. The reason for using ungrounded power systems is to improve the reliability of power to all power using equipments and systems (see paragraphs 300-2.2.2 and 300-2.2.3). A secondary reason is to prevent galvanic corrosion of the hull caused by current flowing through either welded joints or joints of dissimilar metals. An ungrounded power system is never to be considered safe to touch or work on while hot. If a power system is permanently grounded at one point, any accidental ground which may occur on a different leg of the system will immediately cause a fault current to flow. This can be a source of fire and electric shock. On the other hand, if a ground occurs on any leg of a truly ungrounded power system, no current will flow until a second ground occurs on another leg. If the first occurrence of a ground can be detected, and the cause removed by disconnection of the device before the second ground occurs, continuity of power to all parts of the system except the originally grounded device can be assured. Also, the disconnection of the defective unit can be done at a convenient time, rather than having it, or possibly a more vital unit disconnected automatically at some inopportune time. It should be realized that there is no such thing as a truly ungrounded system. However, actual systems have sufficient resistance to limit currents to values which will not usually activate protective devices.

300-3.2.6 GROUND DETECTORS. In order to maintain an ungrounded system for maximum continuity of power, ground detectors are provided to detect and locate grounds as they occur. Ground detectors can be classified as active or passive types. Passive types may be either in the form of lights or voltmeters. To locate the individual circuit causing a ground indication, it is usually necessary to begin at the main distribution panel containing the ground indicator that shows the ground. By selectively opening and closing the protective devices in this distribution panel, the main circuit supplying the ground or the main circuit causing an unbalance (see paragraphs 300-3.2.6.1 through paragraph 300-3.2.6.3.3) can be identified, since the ground indication will be removed when the circuit is opened. In most instances the protective devices in the main panel containing the ground detector supplies other subdistribution panels. In this instance, the troublesome circuit can be further isolated by selectively opening and closing individual protective devices in the subpanel while someone observes the ground indicator at the main panel. By continuing this procedure, grounds can usually be traced to an individual circuit supplying a single item of equipment. Ground indications caused by circuit unbalance are more difficult to isolate since the unbalance may not be due to a single item of equipment having a low impedance to ground, but by a number of items of equipment on the same phase with capacitance (usually filters) to ground. However, the same procedure of selectively opening and closing circuit protective devices can be followed to isolate the cause of a ground indication. In many instances ground indications caused by an unbalance of capacitance can be removed by reconnecting equipment from the phase indicating the ground to one of the other phases of the three-phase system. All wiring changes must be documented.

300-3.2.6.1 Active Ground Detectors. Active ground detectors consist of means of applying dc voltage between an operating power system and ground (see Figure 300-3-1), measuring the current flow, and from this determining the ground resistance of the system. The voltage is obtained through a rectifier and transformer from the 120-volt, single-phase lighting system, and the milliammeter used to read the current is calibrated directly in ohms.

300-3.2.6.1.1 To read the resistance of an energized ac system, the dc output of the ground detector is connected to one of the three lines of the three-phase system. Since all three phases are connected together through the generator with very low dc impedance, the whole system, except parts isolated by transformers, is subjected to the same applied voltage; and the resistance read on the meter is combined parallel resistance to ground from all three legs.

300-3.2.6.1.2 To read the resistance of a dc system, the system voltage must be cancelled out as it would add to or subtract from the voltage obtained from the rectifier and give erroneous readings, if the ground detector voltage were applied to one side of the system. In order to compensate for this, a potentiometer is connected across the system and the movable contact adjusted until the voltage between this point and ground is zero. The output of the ground detector is then applied to the system through the center point of the potentiometer. The resistance of the potentiometer is taken into account in the calibration of the meter.

300-3.2.6.1.3 Since the indication given by an active ground detector is the total ground resistance of the whole system, the interpretation of the reading should be primarily on the basis of its behavior over a period of time, considering the extent of the system energized at the time, with particular emphasis on items known to have lower resistance.

300-3.2.6.1.4 There are certain precautions which must be considered in the application of active ground detectors. Some types of equipment, notably electronic and solid-state devices, are vulnerable to permanent damage as a result of higher than normal voltages to ground. The voltage applied by an active ground detector may add to the normal line voltage causing a high voltage peak to ground. For this reason general practice has been to use a lower voltage ground detector on the 120-volt systems since they are more likely to supply vulnerable types of equipment. Generally the ground detector voltage for 450-Vac and 250-Vdc systems is 500 Vdc; and for 120-volt, 60-Hz or 400-Hz systems it is 150 Vdc.

300-3.2.6.1.5 Since the voltage applied by the ground detector is dc, the readings are not affected by the presence of capacitors on the system.

300-3.2.6.1.6 Maintenance of ground detectors requires only replacement of defective rectifiers, resistors, or rheostats. Care should be taken to replace resistors with units having identical values and power ratings.

300-3.2.6.1.7 Active ground detectors are used primarily on submarines.

300-3.2.6.1.8 On submarines, the minimum acceptable resistance to ground for the ac and dc systems is 50,000 ohms. However, the buses should be maintained as high as possible. Decreasing trends should be investigated. When submarines are receiving electrical power from a submarine tender, insulation resistance, as measured by the active ground detector, will be lower than when power is obtained from the submarine's own generators. This results from all the resistive leakage paths to ground of the energized electrical systems on the two ships being connected in parallel. Typical insulation resistance values may range from 20,000 ohms when power is being supplied to one submarine, down to 5,000 to 10,000 ohms when several submarines are receiving power, depending on the extent of the systems energized. This should not be cause for alarm as long as the readings are relatively stable over a period of time under similar conditions.

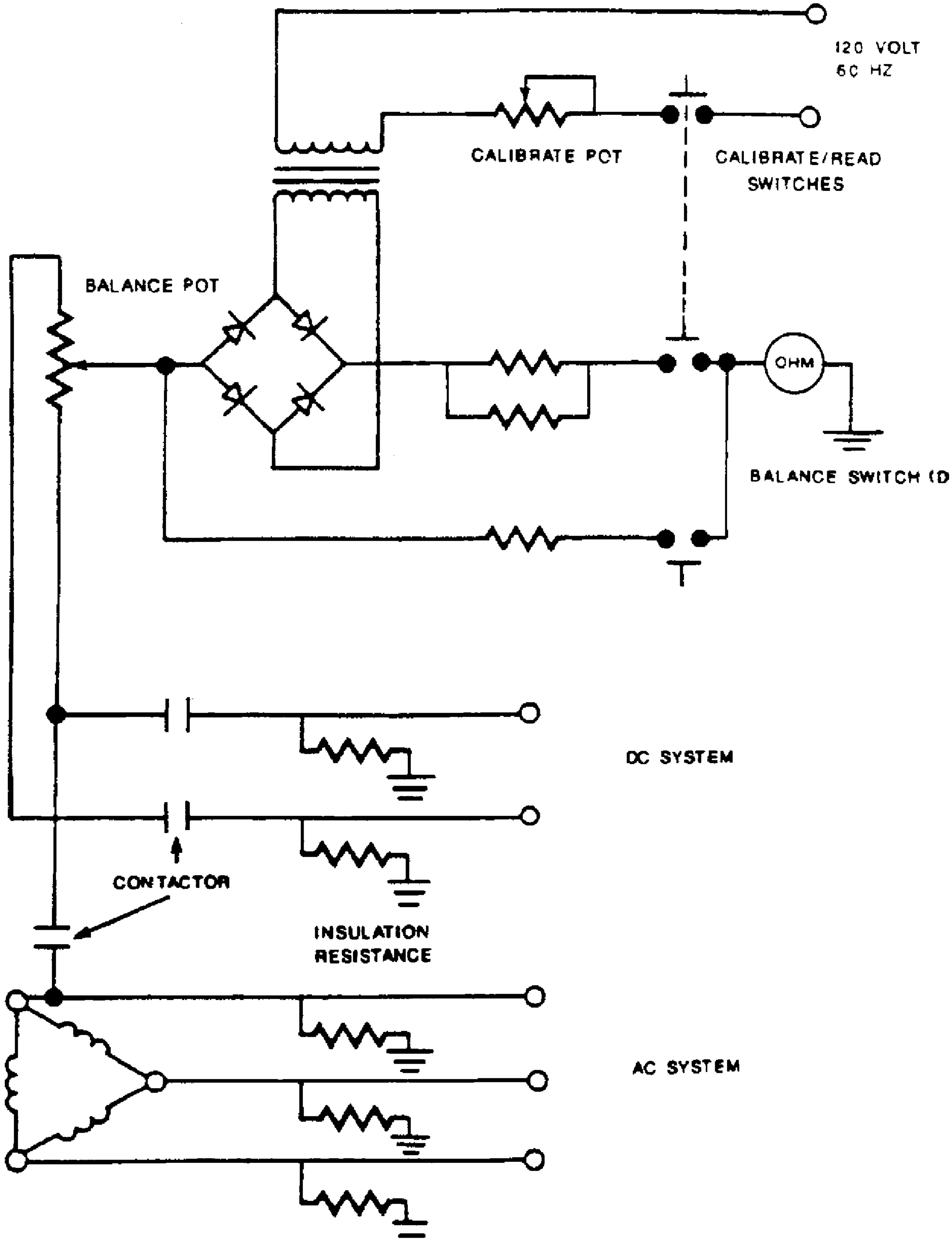


Figure 300-3-1 Active Ground Detector Circuit

300-3.2.6.2 Ground Detector Lights. Ground detector lights consist of two (or three) indicator lights connected in such a way that they burn continuously at a low intensity. Closing a momentary contact switch connects the lights to ground. On a perfectly balanced, 3-phase, ungrounded system the voltage between phase and ground is equal to line voltage divided by the square root of three. If there is an imbalance of impedance to ground on one leg of the system, one light will become dimmer, or extinguished if the unbalance is large, and the other one (or two) lights will become brighter. Depending on the magnitude of the unbalance, the lights will burn at varying intensities. Since no system is perfectly balanced, lights can be expected to glow at varying intensities under normal conditions. Operating personnel should become familiar with the normal test appearance of ground lights. Any appreciable change, such as a light going very dim or going dark, is an indication of a low impedance to ground and the cause should be investigated and corrected (see paragraph 300-3.2.6).

NOTE

> Lamp wattages of between 5 and 25 watts when operating at 1/2 phase-to-ground voltage have been found to perform adequately, giving a viewer adequate illumination contrast for high impedance grounds. Should a solid ground occur, the lamps will still be within their rating and will not be damaged. For lesser grounds, the lumen output of the lamps will vary approximately proportional to the cube of the voltage. This exponential change in lamp brightness (increasing in two and decreasing in one) provides the necessary contrast.

300-3.2.6.2.1 Typical circuits for two-wire dc and for three-phase ac systems are shown in Figure 300-3-2. The transformer ratios and resistors are selected to give approximately full rated voltage on the light, if one line is grounded with zero resistance.

300-3.2.6.2.2 The circuit for dc systems in Figure 300-3-2A is such that the voltage across one lamp, as compared to the other lamp, is determined by the difference between the two ground resistances. The lamp having the higher resistance in parallel with it will be brightest. Regardless of how high or how low the ground resistance is, if it is the same on all legs, the lights will all burn at the same brightness. Therefore, a ground detector light system cannot show the condition of general distributed insulation resistance. It does, however, show readily when one leg of the system has a much lower resistance than the others. It can be shown that one light will be approximately twice as bright as the other (on a two-wire 250-Vdc system) when a ground resistance of 10,000 ohms or lower appears on one side.

300-3.2.6.2.3 Ground detector lights do not indicate the absolute level of ground resistance. They only give an indication of the unbalance between line voltage and ground caused by the difference in ground resistances. For this reason some variance in light intensity can be expected and should be considered normal. On the other hand, ground lights cannot injure any equipment since system voltage is all that can appear between any line and ground as a result of depressing the pushbutton.

300-3.2.6.2.4 On ac systems, as shown in Figure 300-3-2B, any capacitance to ground that exists as a result of distributed capacitance of cables or filters connected to ground will affect the brightness of the lamps in the same manner as leakage resistance. The greater the unbalance of capacitance to ground between phases, the greater the difference in light intensities between the ground light lamps. On relatively small distribution systems, a small capacitor connected from phase-to-ground can cause a large unbalance in phase-to-ground voltage and cause ground lights to glow at various intensities or even cause a light to go dark. When it has been confirmed that one light barely glows or goes dark because of an unbalance in capacitance and not because of a low-resistive path to ground and the circuitry does not permit balancing of filter capacitance to ground between phases (see paragraph 300-3.2.6), the addition of 0.5 microfarad capacitors to the ground detector panel, as shown in Figure 300-3-2D, is an approved method to increase the system capacitance artificially. The addition of these capacitors reduces the capacitance unbalance to a level that should cause the ground detector lights to burn closer to equal intensities. This modification will not reduce the effectiveness of the lights to indicate a breakdown of insulation between phase and ground.

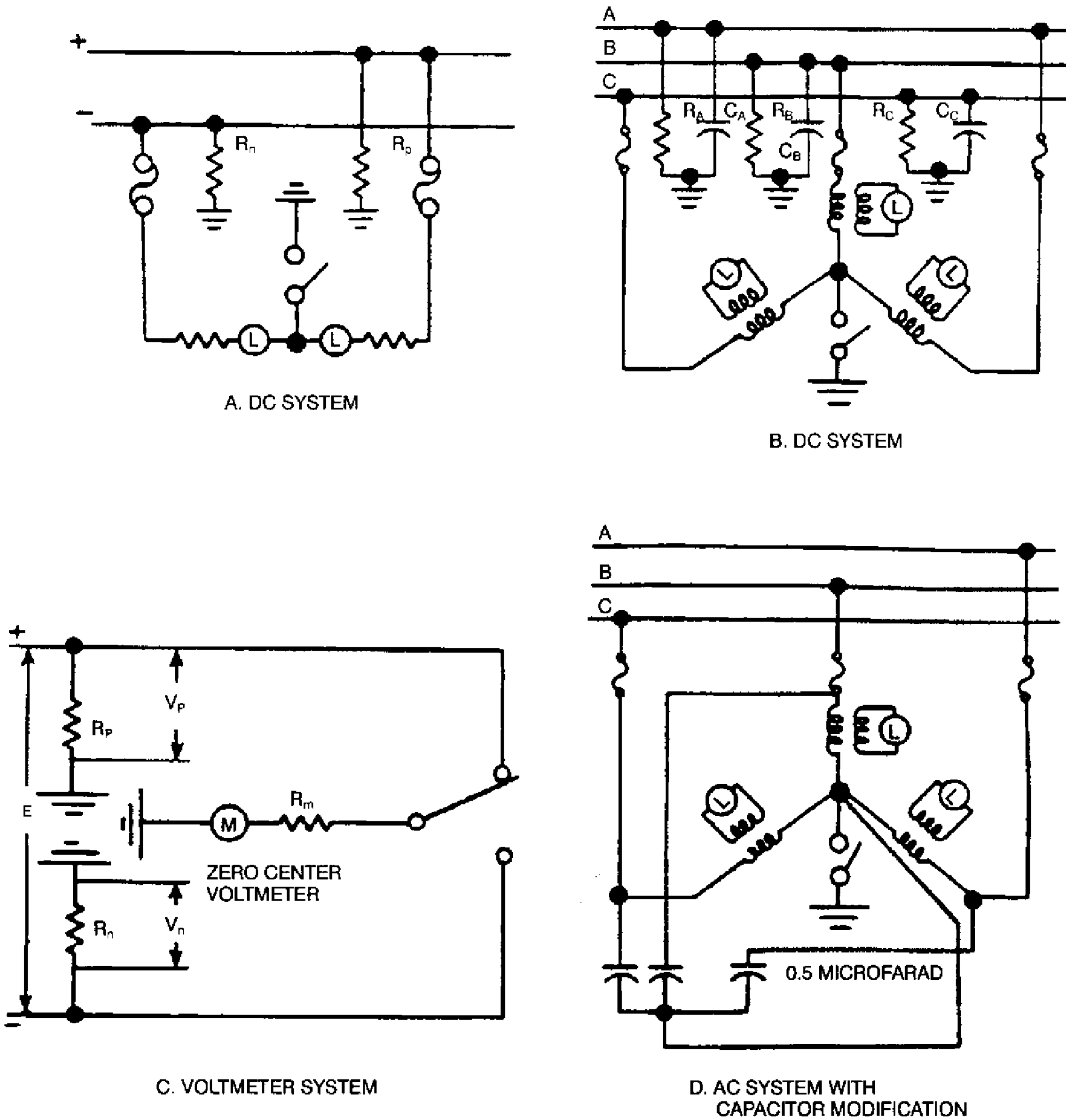


Figure 300-3-2 Typical Ground Detecting Circuitry

300-3.2.6.2.5 The only maintenance required on ground detector light systems is the replacement of defective parts. Care must be taken to replace lamps and resistors with units of identical characteristics to those originally installed.

300-3.2.6.3 Ground Detector Voltmeters. A ground detector voltmeter system consists of a zero center voltmeter connectable between ground and each of the legs of a power system.

300-3.2.6.3.1 Ground detector voltmeters are usually used on dc two-wire systems, but can be used in ac single or three-phase systems. In some cases the installed system voltmeter is used and the voltmeter selector switch is arranged to connect the meter successively between each leg of the system and ground, reversing the polarity (on dc systems) as necessary to assure that the meter will read up scale.

300-3.2.6.3.2 A typical two-wire dc installation is shown in Figure 300-3-2C. By using the voltages read on the meter for each connection, together with the system voltage, and knowledge of the meter internal resistance, the system impedance to ground for each leg can be calculated. The equations for doing this are as follows:

$$R_g = \frac{1}{\frac{1}{R_p} + \frac{1}{R_n}} = \frac{R_p R_n}{R_p + R_n}$$

$$R_g = \frac{R_m(E - V_p - V_n)}{V_p + V_n}$$

$$R_p = R_m \frac{E - (V_p + V_n)}{V_n}$$

$$R_n = R_m \frac{E - (V_p + V_n)}{V_p}$$

E = System voltage

R_p = Resistance between positive leg and ground

R_n = Resistance between negative leg and ground

R_g = Combined system resistance to ground

R_m = Voltage resistance (including any external resistors)

V_p = Reading of voltmeter when connected to positive leg

V_n = Reading of voltmeter when connected to negative leg. Even though the deflection of the meter (on a zero-center meter) when connected to this side will be in the opposite direction to V_p, a positive value should be given to this reading when using the equations.

300-3.2.6.3.3 Ground detector voltmeters on ac systems, like ground detector lights, cannot differentiate between resistance and capacitance to ground. Therefore, their indications can only be interpreted if there is some knowledge of the capacitance of the system. As with lights, ground detector voltmeters cannot cause injury to any equipment on the system. Maintenance of ground detector voltmeter systems is the same as for any other voltmeters and switches.

300-3.2.7 GROUNDED POWER SYSTEMS. There are three common types of grounded electrical systems that find limited application on Naval ships (see paragraph 300-2.2.1.5. One type has one of the phases grounded as shown in Figure 300-3-3A. A second type has a grounded neutral connected at the center point of one of the transformers as shown in Figure 300-3-3B. The third type has the grounded neutral connected as shown in Figure 300-3-3C. Some small craft have 60 Hz systems as shown in Figure 300-3-3C. Aircraft servicing and avionics shops have 400 Hz systems as shown in Figure 300-3-3C. On these grounded systems, insulation resistance measurements of complete circuits cannot be measured without first removing the permanently connected path to ground. The procedure of removing the ground is not recommended during routine insulation measurements unless there is a strong indication that a ground exists other than the intentional ground at the panel or power source. The ground or neutral ground discussed in this paragraph should not be confused with safety grounding of equipment enclosures and chassis by their mounting or ground straps, or the third wire (green wire) ground used in many instances for grounding equipment mounted on non-conducting surfaces or for portable equipment grounding (see paragraphs 300-2.2.1.1 through 300-2.2.1.4.1). Safety ground requirements are the same for equipment supplied by either a grounded or an ungrounded system.

300-3.2.8 MEASUREMENT PRECAUTIONS. The measured value of insulation resistance depends not only upon the properties of the insulation, but also upon the magnitude of the voltage used in making the test, the length of time the test voltage is impressed before reading the insulation resistance, the presence or absence of residual charge, and the temperature of the equipment being measured. These factors, therefore, should be the same in tests made at different times in order to obtain comparable results.

NOTE

Insulation resistance measurements should not be performed while connected to a grounded shore power supply. Readings taken thus will give erroneous resistance values.

300-3.2.8.1 Test Voltage Magnitude. Insulation resistance may decrease to a certain extent as the test voltage used for its measurement is increased. The same test voltage, therefore, should be used in all tests made at periodic intervals on the same piece of equipment. Instruments normally supplied for shipboard and naval shipyard use for measuring insulation resistance are provided with a 500-Vdc source. This may be safely applied to cables and both armature and field windings of all shipboard ac and dc rotating equipment which receives routine insulation resistance tests. It is, however, too high for certain electronic equipment and radio frequency interference filters which contain capacitors that may be broken down by 500 volts. Disconnect such equipment when making insulation resistance measurements with a 500-volt instrument. Instruments of 1,000 volts and 2,500 volts are suitable for measuring the insulation resistance of ac stator windings rated at 2,000 volts or more but should not be used on circuits or equipment rated at lower voltage.

300-3.2.8.2 Duration of Test Voltage Application. When the test voltage is initially applied, the insulation resistance will gradually increase for an appreciable period of time, particularly in long cable runs and large machines. The time delay is required to charge the capacitance in the system. Capacitance is present in all systems, not only from capacitors in equipment, but from the inherent capacitance between cables and between cables and ground. In short cable runs and machines below 1,000 kilowatts, this effect is not so pronounced. When making measurements, the test voltage should be applied until a constant reading is obtained. Hand-driven generator type instruments should be cranked for at least 30 seconds to ensure a steady reading. In cases where it is impossible to crank the instrument until a steady reading is obtained, it should be turned as long as practical and subsequent tests made for the same length of time so that the readings will be comparable.

300-3.2.8.3 Residual Charge. Residual charges retained in insulation affect the readings of insulation resistance, especially in large machines and long cable runs. When measuring the insulation resistance of machines above 500-kilowatt capacity, it is recommended that the conductors be grounded and discharged for a few minutes prior to the measurements. A short length of cable with clips attached at each end will be found convenient for this purpose. Separate circuits may be discharged simultaneously by connecting all circuits together and to ground. Personnel should exercise caution against the possibility of receiving shock due to contacting windings before they have been discharged. This applies especially to large ac propulsion generators and motors.

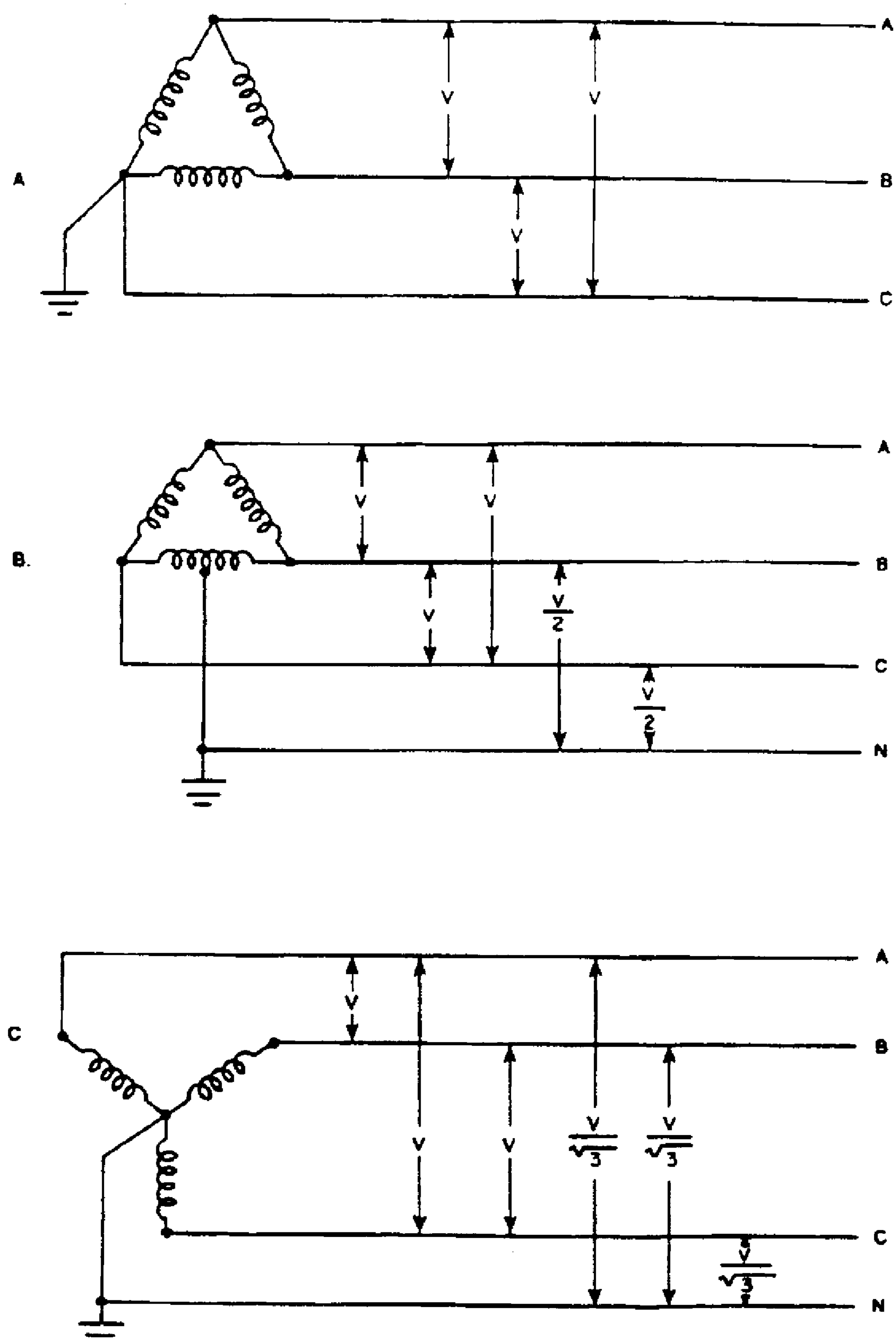


Figure 300-3-3 Typical Grounded Systems.

300-3.2.8.4 Temperature. Refer to paragraphs 300-3.3.1.3 through 300-3.3.2.2 for cable and 300-3.4.1.3 for rotating electric machinery for guidance in handling the effects of temperature on insulation resistance.

300-3.3 CABLE INSULATION RESISTANCE

300-3.3.1 FACTORS. The primary purpose of making insulation resistance measurements of shipboard cable installations is to determine the condition of the cable so that deterioration and incipient failure may be discovered and remedied. However, in order to arrive at a reliable conclusion regarding the condition of the cable, it is necessary to evaluate each of several factors, which have a significant effect on insulation resistance measurements in addition to the condition of the cable.

300-3.3.1.1 Other Apparatus Connected in Circuit. A true conclusion regarding the cable condition cannot be reached if other equipment is connected in the circuit when the measurement is made. For example, when measuring the insulation resistance of the positive cable connecting a generator to a switchboard, the cable should be disconnected at each end. If this is not done, the measurement will include the insulation resistance of the bus work, all apparatus connected to the bus, the generator, and the negative cable. Since the insulation resistance of this other apparatus is in parallel with that of the cable, the measured value of the combination may be considerably lower than that obtained if the cable is disconnected and measured separately. See paragraph 300-3.2.2.1. For convenience it may be desirable to make initial measurements with the cable only partially isolated by opening the switches, circuit breakers, or other disconnecting devices provided in the circuit. If such measurements indicate resistances are above the minimum acceptable value or within limiting values, no further isolation of the cables may be necessary. However, if the resistances are low in comparison to the desired standard, it will be necessary to disconnect the cable completely and measure it alone before concluding that the cable is responsible for the condition. When making measurements it may prove helpful to record the exact amount of other equipments included in the circuit in order to make significant comparisons with similar past or future measurements.

300-3.3.1.2 Total Quantity of Cable. Insulation resistance of a cable varies inversely with length. The insulation resistance of a length of cable is the result of a number of small individual leakage paths or resistances distributed along the cable and connected between the conductor and the cable sheath. Assume, for example, that one of these leakage paths exists in each foot of cable. Then in 10 feet of cable there would be 10 such paths for current to flow between the conductor and the sheath, and the total amount of current flowing in all of them would be 10 times as great as that which would flow if the cable were only 1 foot long. In other words, the longer the cable the more leakage paths exist and hence the lower the insulation resistance. In order to have a common unit of comparison, cable-insulation resistance should be expressed in megohms (or ohms) per foot of length. This is determined by multiplying the measured insulation resistance of the cable by its total length in feet. The total length is determined as follows:

a. For single conductor cable the total length is equal to the length of the cable sheath.

b. For multiple conductor cable, the total length depends partly on how the conductors are used in the circuit while the measurements are being taken. If the cable is isolated from all equipment or goes from switch to switch, the total length is equal to the length of the cable sheath. For example, a type TSGA cable, conforming to MIL-C-24643/16, has a cable sheath length of 300 feet and three conductors which are phases A, B, and C of a three-phase power circuit. The total length of cable to be used in converting measured insulation resistance to insulation resistance per foot is 300 feet, not three times 300 feet. The reason is that each conductor is measured separately. If the cable is connected in series, to a similar cable which has a sheath length of 300 feet, the total length is 600 feet. As another example, the total length of 300 feet of type MSCA-7, 7-conductor cable conforming to MIL-C-24643/18, is 300 feet, not 7 times 300 feet; and 300 feet of type

MSCA-7 connected to 300 feet of type MSCA-2A represents a total cable length of 600 feet. If the conductors in a cable are connected in series with each other, the total cable length will be the number of serially-connected conductors times the sheath length.

c. For multiple conductor degaussing coil cable, the total length is the length of the cable sheath times the number of conductors. This is because degaussing cable is installed in the form of a loop and the conductors in multiple conductor cable are connected in series where the ends of the cable meet to make a single coil with as many turns as there are conductors in the cable. For example, the total length of a 19-conductor MDU cable, conforming to MIL-C-24643/5 with a cable sheath length of 500 feet is (500) x (19) = 9,500 feet.

300-3.3.1.3 Type of Cable. Insulation resistance varies considerably with the nature of the insulation material employed and the construction of the cable. It is possible to judge the condition of a cable as determined by its measured insulation resistance only when considered in relation to the typical characteristics of the particular type of cable. Figure 300-3-4 and Figure 300-3-5 provide means for determining if the measured insulation resistance values are above the minimum acceptable values. Figure 300-3-4 is applicable to large single conductor propulsion power cables. Figure 300-3-5 is applicable to all cables except degaussing cables and large single conductor propulsion power cables. See paragraph 300-3.3.2.2.1 for acceptable insulation resistance of degaussing cable and for portable shore power cables.

300-3.3.1.3.1 Points 1, 2, and 3 of Figure 300-3-5 cover cable types of power, lighting and control at temperatures of 60°C (140°F), 21°C (70°F), and 4.4°C (40°F), respectively, while points 4, 5, and 6 cover telephone and audio cables at these same temperatures. It should be noted that these temperatures are assumed ambient temperatures, and not that of the sheath as was previously used in measuring insulation resistance of power and lighting cables.

300-3.3.1.3.2 The large propulsion power cable resistance vs temperature characteristics illustrated in Figure 300-3-4 show that a nominal resistance change from about 3,000 megohms-per-foot may occur in the normal operating temperature range of -2.2° to 85 °C (28° to 185°F) as measured at the cable sheath. The cable sheath temperature shall be considered in conjunction with the insulation resistance measurements of large single-conductor propulsion cables. For large single-conductor propulsion power cables, the cable sheath temperatures may normally be estimated from past experience with sufficient accuracy to determine that the cables are in satisfactory condition. If the results obtained by estimating the temperature indicate values of insulation resistance approaching the limiting values indicated on the curve, temperature measurements of the cable should be made.

300-3.3.1.3.3 Fairly accurate measurements of the temperature of the sheath of the cable must be made to permit a reliable interpretation of the insulation resistance of propulsion power cables and proper use of Figure 300-3-4. The temperature should be measured by means of thermometers attached to the cable sheath or armor at several points along the length of the cable and these values averaged. The thermometer bulb should be placed in direct contact with the sheath or armor, scraping away the paint at the point of contact and holding the thermometer in place by pads of felt or other heat-insulating material placed over the bulb and secured with tape. The number of thermometers used and their location should be such that they indicate a representative average of the sheath temperature of the entire cable being measured.

300-3.3.2 BASIS OF ACCEPTANCE. Insulation resistance values for each complete power circuit shall be at least 1 megohm and for each complete lighting circuit shall be at least 0.5 megohm. If the values are below these minimums, corrective action shall be taken.

300-3.3.2.1 Measurement Criteria. If successive isolation of components from the circuit indicates that the low insulation resistance is due to the cables, the acceptance values which shall be used to judge whether or not a cable is safe to operate depend upon temperature, cable length, and the type of cable. Measurements shall be made immediately upon deenergizing the circuits which have been energized for at least 4 hours; otherwise, measurements shall be made after the circuit has been deenergized for at least 4 hours. Circuits which have been deenergized for at least 4 hours shall be classed as being either in a warm ambient or in a cold ambient environment. A warm ambient is defined as a warm climate or a condition in which the entire cable is in a heated space and not in contact with the ship’s hull. A cold ambient is defined as a cold climate or a condition in which most of the cable is in an unheated spaced or is against the ship’s hull in cold waters. The cable temperature shall be considered to be 40°C (104°F) if the cable has been energized for 4 hours, 21.1°C (70°F) if it is de-energized for 4 hours in a warm ambient, and 4.4°C (40°F) if it is deenergized for 4 hours in a cold ambient.

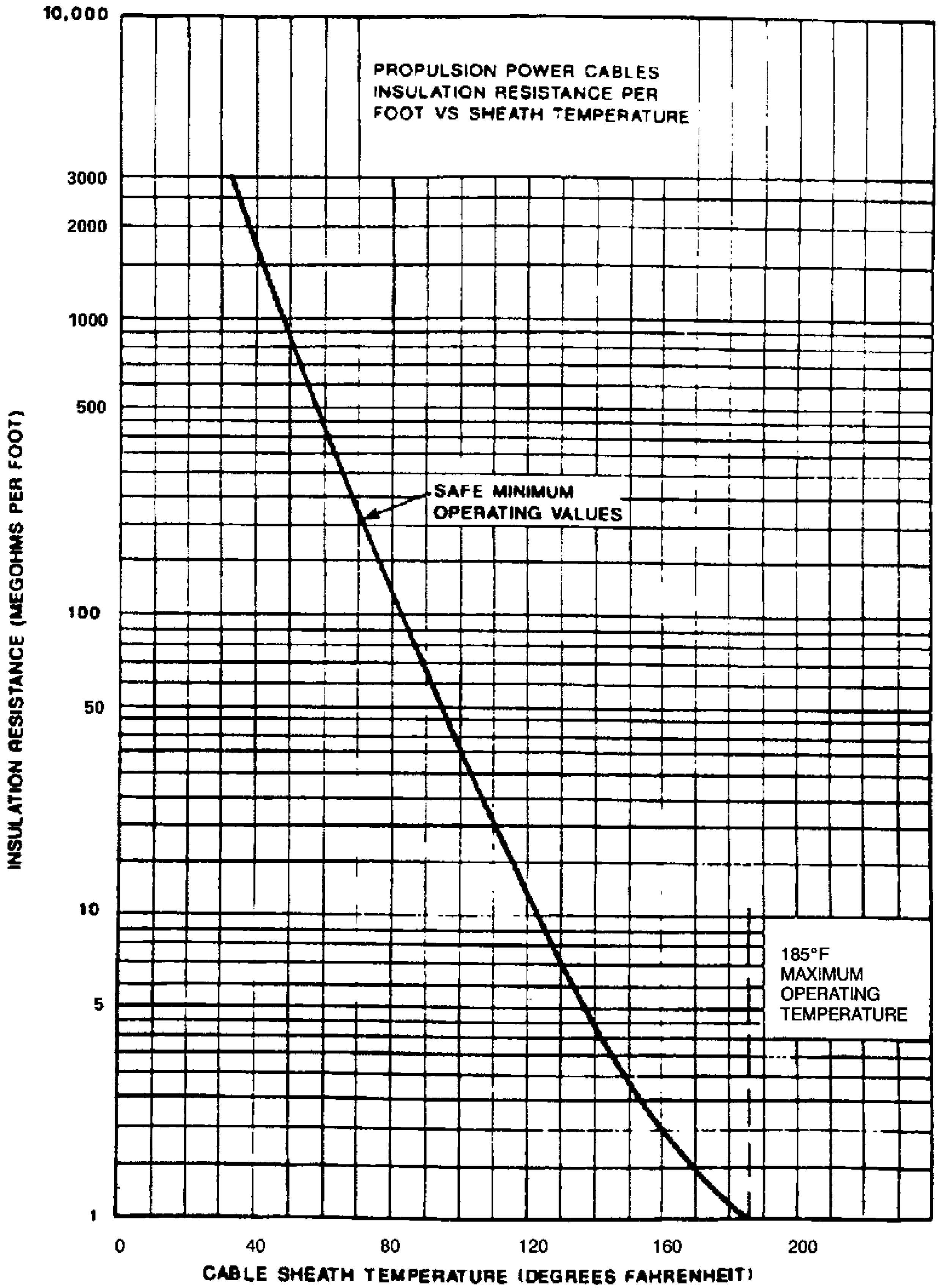
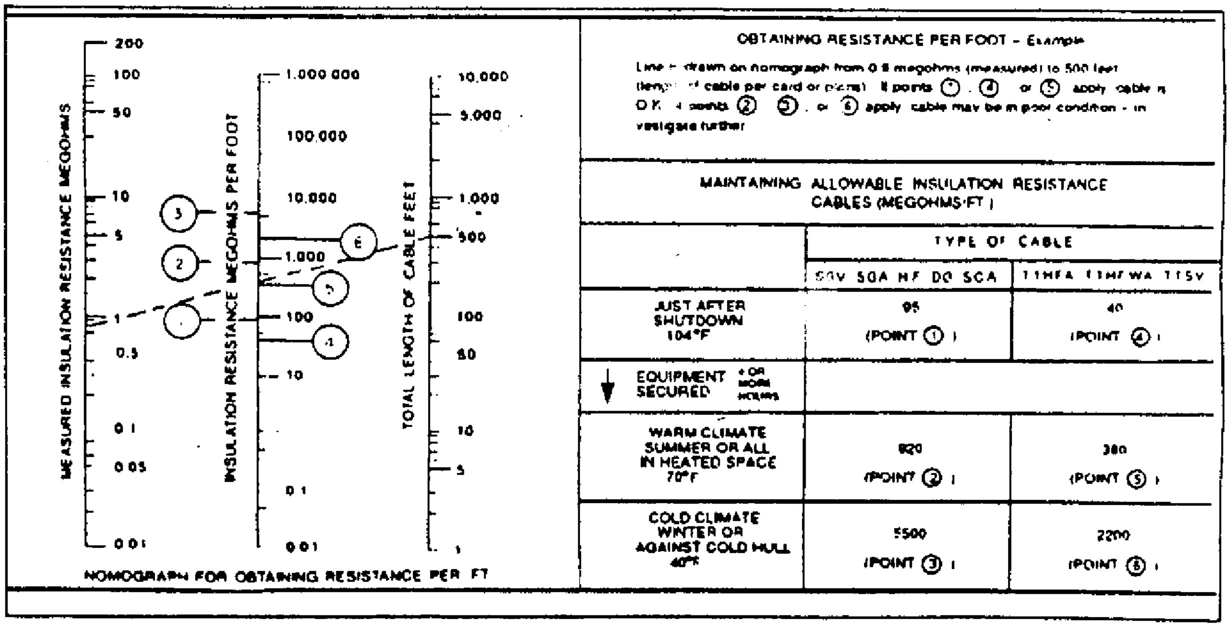


Figure 300-3-4 Propulsion Power Cable Resistance Versus Insulation Temperature



NOTE: DATA COLLECTED FOR EACH CABLE TESTED SHOULD BE RECORDED IN THE APPLICABLE WORK CENTER LOG

Figure 300-3-5 Insulation Resistance - Temperature Nomogram (For use with cables, resistance per foot)

300-3.3.2.2 Use of Nomograph. On Figure 300-3-5, select the point of allowable resistance per foot based on the ambient condition and the type of cable. Using the nomograph, a straight line from the measured insulation resistance to the length of cable should cross the resistance per foot line above the selected minimum resistance per foot point. Corrective action is required if the resistance per foot is less than the selected point.

300-3.3.2.2.1 For degaussing cables, if the insulation resistance is less than 0.1 megohm, corrective action shall be taken. For portable shore power cables supplied by tending activities, if insulation resistance is below the limit set in ship's shore power instructions or is less than 0.5 megohm, corrective action shall be taken before connecting the cables.

300-3.3.2.2.2 If lower values for particular circuits have previously been determined to be satisfactory (see paragraph 300-3.3.3.2.3 also), these shall be considered the minimum acceptable values.

300-3.3.2.2.3 For propulsion power cables, the values given in Figure 300-3-4 shall be used to indicate the necessity for corrective action.

300-3.3.3 PROCEDURE. The following procedure is recommended for determining the insulation resistance of power, lighting, and degaussing circuits. See **NSTM Chapter 235, Electric Propulsion Installations,** for measurement of insulation resistance of electric propulsion installations and **NSTM Chapter 430, Interior Communication Installations,** for measurement of insulation resistance of interior communication and fire control circuits.

300-3.3.3.1 Initial Check. In order to avoid unnecessarily disconnecting apparatus with resultant expenditure of time and labor, and possible damage to cables by handling, approximate checks of insulation resistance of complete circuits should be conducted. For this purpose, the circuit includes installed cables, the terminals of equipment, and those internal parts of equipment which remain connected to the terminals such as bus bars, switches, fuse clips (with fuses in place), and so forth. Equipment which cannot withstand the 500 volts applied by the megohmmeter (megger), shall be disconnected.

300-3.3.3.2 Circuits Under Test. The circuits to be initially measured should be considered as beginning at the open switch or circuit breaker on the switchboard, from which the potential is supplied, and extending to its extremity as illustrated in Figure 300-3-6 and Figure 300-3-7. The legs or phase leads to be measured in the circuit should include the following:

a. Lighting circuits. The legs or phase leads should include all panel wiring, terminals, connection boxes, fittings, fixtures, and outlets that are normally connected, but with all plugs removed from the outlets.

NOTE

Where local lighting switches are double pole, the insulation resistance to ground and between conductors of local branch circuits and fixtures is not measured when the switch is open, since both conductors in each of the local branch circuits are isolated by the open switches. However, it can be determined whether grounds exist on local branch circuits and fixtures in such cases by making an insulation resistance test from one leg or phase lead to ground with the local switches closed. Circuit isolation shall be used only to the extent necessary to determine the cause of the low insulation resistance if the measured values are below the acceptable limits given in paragraphs 300-3.3.2 through 300-3.3.2.2.3.

b. Power circuits. The legs or phase leads should include panel wiring, terminals, connection boxes, fittings, outlets (with all plugs removed), motor controller terminals, and other apparatus which remains connected when the phase lead or the leg is isolated by opening circuit breakers, or switches, at the switchboards and by leaving motor controller contactors open.

c. Degaussing circuits. Measurements should be taken at the degaussing connection box. The legs should include the coil cables, through boxes, and feeder cables. The supply and control apparatus should be disconnected by opening the circuit on the coil side of the control equipment (or motor generator set in installations of that type). Measurement of the compass coil feeder cable should be made with all control equipment disconnected. See **NSTM Chapter 475, Magnetic Silencing,** for additional information on tests of degaussing installations.

300-3.3.3.2.1 Measurements of the circuit as defined above should be made on each individual leg of dc circuits and each individual phase lead of three-phase ac circuits. For example, measurements of three-conductor cable circuits should be made as follows (see Figure 300-3-8):

1. Ground the cable armor if not already grounded; normally this has been accomplished as part of the installation by means of the cable straps or other contacts between the armor and the metal structure of the ship.
2. Connect two legs or phase leads together and ground them by means of temporary wires or clipped test connections.
3. Measure the resistance of the third leg or phase lead to ground.
4. Repeat steps 2 and 3 so as to measure each leg or phase lead to ground.

NOTE

For circuits containing permanently connected metallic paths between legs or phases (such as distribution transformers, instrument transformers, indicator lights, and control relays) measurements need be made only between one conductor and ground, unless low values requiring further tests are obtained, in which case opening of additional connections and tests of individual legs or phases should be accomplished.

300-3.3.3.2.2 The circuit insulation resistance values measured in accordance with the foregoing should be considered satisfactory if they are above the minimum values defined as the basis of acceptance in paragraphs 300-3.3.2 through 300-3.3.2.2.3.

300-3.3.3.2.3 The minimum value obtained on an identical circuit (same cable and apparatus connected) at approximately the same ambient temperature of the cable in any previous insulation resistance test, provided that value has been established as satisfactory by investigation and satisfactory service operation, shall be considered acceptable. It should be noted that if no previous value has been established which may be used for comparison purposes, further segregation and analysis of the cable and circuit components will result in establishing a value that should be recorded in the applicable work center log when required, and used in insulation resistance tests conducted thereafter.

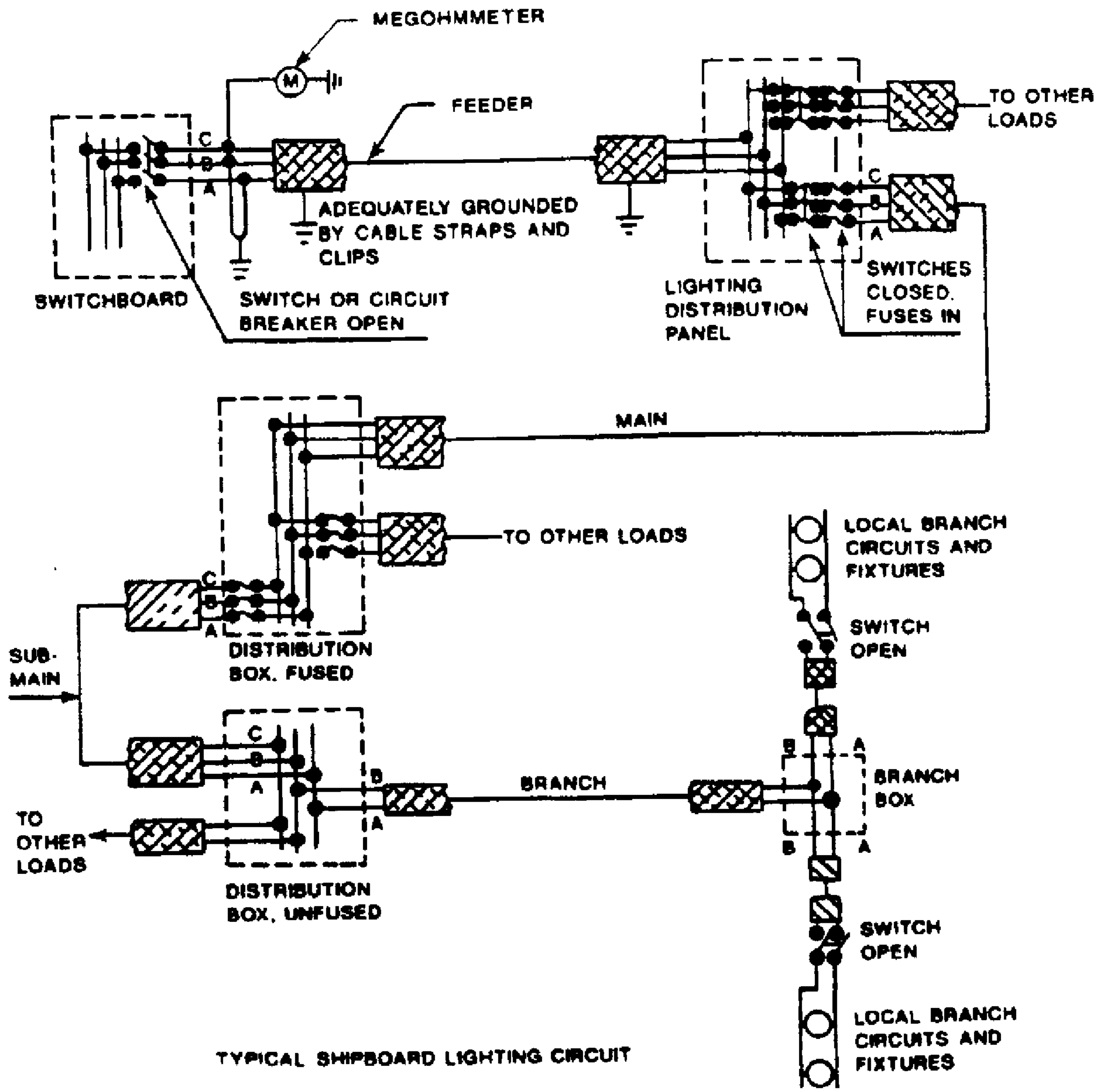


Figure 300-3-6 Measuring Lighting Circuit Insulation Resistance

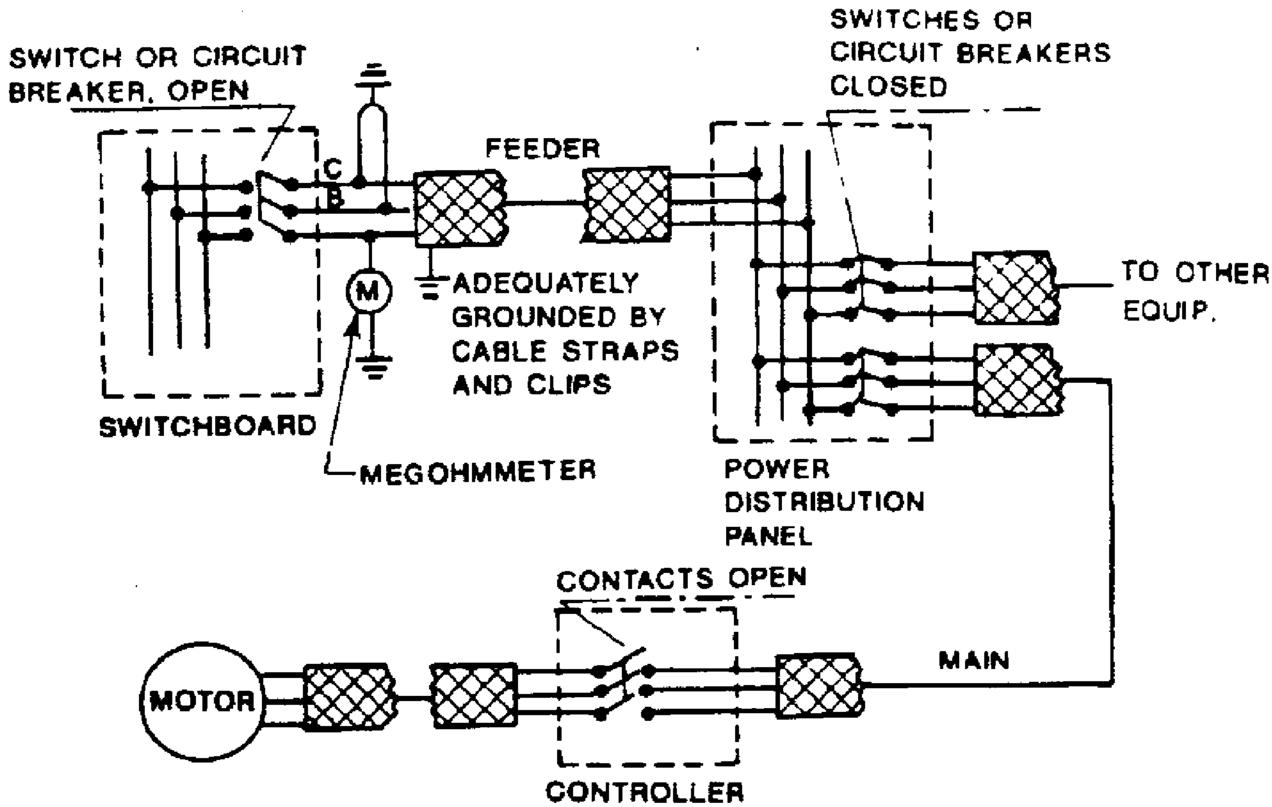


Figure 300-3-7 Measuring Power Circuit Insulation Resistance

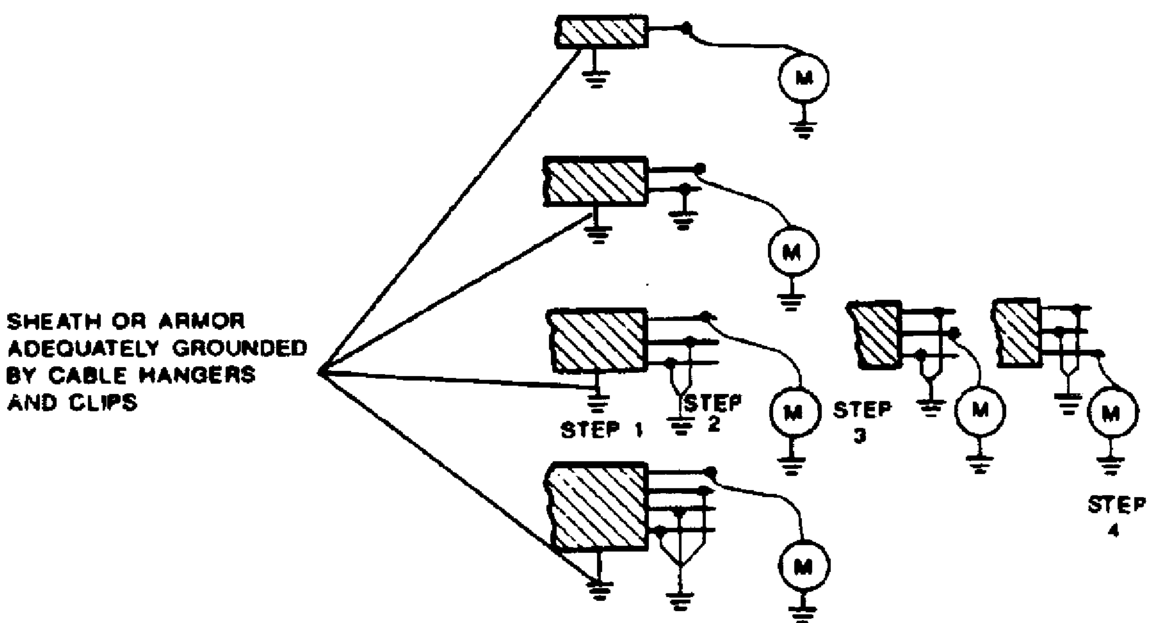


Figure 300-3-8 Measuring Insulation Resistance of Cable Circuits (Typical)

300-3.3.3.2.4 Insulation resistance values need not be recorded except in those instances of minimum resistance values, or when physical damage has occurred, or whenever there is evidence of a contaminant having leaked on the cables. Records may be destroyed when it has been ascertained that the situation has become satisfactory as evidenced by a constant acceptable value of insulation resistance when measured daily for one week.

300-3.3.3.2.5 In those instances where the insulation resistance of a circuit is less than the minimum value described in paragraphs 300-3.3.2 through 300-3.3.2.2.3, the low value may be due to trouble localized in a segment of the circuit. To determine whether this is the case, segregate the circuit into two or more parts by opening switches, opening circuit breakers, removing fuses, and so forth at the feeder distribution panels and boxes. Conduct an insulation resistance test on each segment of the divided circuit in accordance with the foregoing instructions. One or more of the segments may indicate abnormally low insulation resistance as compared with other segments of approximately equivalent length and extent. If such is the case, the relatively low reading value obtained on the segment of the circuit may be due to low insulation resistance at the cable junction with terminals, or in apparatus remaining connected. This possibility should be investigated by inspecting and checking all cable junctures, apparatus (fixtures, fittings, wiring appliances) remaining connected in the phase lead or leg of the segment in question. Possible causes of low insulation resistance such as faulty connections, accumulations of dirt, and foreign materials, should be corrected by cleaning or other action as necessary. After this inspection and cleaning, the insulation resistance of the phase lead or leg should be measured again and the value compared with values obtained before inspection and cleaning.

300-3.4 INSULATION IN ROTATING ELECTRIC MACHINERY

300-3.4.1 FACTORS. The insulation resistance of the windings on a piece of rotating electric machinery is affected by the construction of the machine, moisture, temperature, cleanliness, and condition of insulation.

300-3.4.1.1 Construction. Dimensions, shape, number of turns, type of insulation, and process of manufacture all influence the insulation resistance of a winding. Windings in large or low voltage machines will have inherently lower insulation resistances than those in small or high voltage machines. Field windings will have inherently higher values than dc armature windings or ac phase windings. Under equivalent conditions, dc armature windings will have lower insulation resistance than phase windings of ac machines of equivalent capacities due to the numerous creepage paths at the commutator connections. The types of bonding and coating varnishes and the drying processes used also have considerable influence. Duplicate machines constructed in the same shop will differ in their insulation resistance because of the variations that occur in their manufacture.

300-3.4.1.2 Moisture. When insulation stands in a moist atmosphere, it absorbs moisture and its insulation resistance decreases. The amount of moisture absorption is increased by increased time of exposure or by an increase in the relative humidity of the atmosphere. It also depends upon the type of insulation and its condition. Cotton, paper, and asbestos insulating materials absorb moisture more readily than mica. High reliability windings, in accordance with Appendices B and C, seal out moisture more effectively than built-up or immersion-impregnated windings. Insulation that has cracked or is otherwise damaged usually is more susceptible to moisture absorption. Since moisture may be driven off or evaporated by the application of heat, the insulation resistance of a winding having a low resistance due to the presence of moisture may be restored by energizing or externally heating the winding.

300-3.4.1.3 Temperature. As in the case of cables (paragraphs 300-3.3.1.3 through 300-3.3.1.3.3), the insulation resistance of the windings on rotating electric machinery decreases as the temperature of the winding insulation increases. Insulation resistance measurements can be properly compared only when taken at approximately the same temperature or when due allowance is made for difference in temperature. For a specific winding, periodic measurements made at normal operating temperature, that is, immediately after shutdown, will furnish a series of measurements at approximately the same winding temperature. To minimize the effect of winding temperature when comparing the results of insulation resistance measurements made at different temperatures, or when applying the recommended minimum values of insulation resistance as given in Table 300-3-4, Table 300-3-5, Table 300-3-6, Table 300-3-7 and Table 300-3-8, it is necessary that the test values be corrected to a 25°C base. The correction is made conveniently by use of Figure 300-3-9. Figure 300-3-9 is based on doubling of insulation resistance for each 10°C decrease in temperature (above dew point). The typical insulation systems used on modern naval rotating electrical equipment have been shown to follow the nomograph in the 10°C to 110 °C region of the scale more closely than at the extremes. Therefore, use of the nomogram should be limited to the correction of insulation resistance in the range of 10°C to 110 °C, both onboard ship and in the shop. Find the measured value of insulation resistance on the left scale and the winding temperature at which the resistance was measured on the right scale. Pass a straight line between these points. The point where this line cuts the middle scale gives the insulation resistance corrected to 25°C (77°F). When making temperature corrections to insulation resistance measurements, the temperature from which the correction is made; that is, the temperature in the right column of Figure 300-3-9, is the machine's winding temperature. When correcting insulation resistance, the winding temperature must be measured if the machine has been recently operated. If the machine has not been recently operated for several hours, the winding temperature will be the same as room temperature and it is only necessary to measure the room temperature. See paragraph 300-3.1.7 for measurement methods. If the windings are not accessible, a measurement on the equipment's exterior, as close as possible to the winding, is acceptable. In this instance, because the equipment's exterior is cooler than the winding, the temperature corrected insulation resistance, obtained from the nomograph, will be less than the value based on the actual winding temperature. If this value of temperature corrected insulation resistance is less than the minimum requirements, either of the following actions are recommended:

1. When the machine's exterior temperature has cooled to the ambient temperature, measure the insulation resistance and the ambient temperature and correct using the nomograph described above.

2. Using the resistance method of paragraph 300-3.1.6.2, winding temperature can be calculated with the following formula:

$$\text{Winding temperature, C}^\circ = (234.5 + t_c)\frac{R_h}{R_c} - 234.5$$

Where R_c = Cold resistance of winding

R_h = Hot resistance of winding

t_c = Temperature (°C) of winding when cold resistance was measured

300-3.4.1.4 Cleanliness. A winding in good condition in all other respects may have a low insulation resistance due solely to deposits of foreign matter and the insulation resistance may increase to an acceptable value after a thorough cleaning. Machines operating in dusty or dirty atmospheres rapidly accumulate foreign deposits on their windings. Armature windings in dc machines are more affected by foreign deposits than armature windings in ac machines because of the exposed copper at the commutator. Direct current machines are also more exposed to carbon and copper deposits from the brushes and commutator, particularly machines having closed ventilating systems. Consequently, the type and construction of a machine and operating conditions influence the rate at which foreign matter is deposited on the windings and the frequency with which a machine must be cleaned.

300-3.4.1.5 Condition of Insulation. Insulating materials deteriorate with age because of the individual or combined effects of heat, moisture, vibration, mechanical damage, dust, oxidation, and chemical action as from acid or alkali fumes, salt, air, or oil. The rate of deterioration depends upon the conditions to which the equipment is exposed and under which it operates, such as location, type of service, load, atmosphere, and amount of care. Even with the best of care, oxidation and corrosion may continue and cause deterioration, particularly if the machine is standing idle.

300-3.4.1.5.1 Insulation resistance decreases as insulation deteriorates, other factors assumed constant. For this reason, a comparison of insulation resistance values over a period of time is of assistance in determining the condition of the insulation and its suitability for service.

300-3.4.1.5.2 A high value of insulation resistance does not necessarily indicate that the insulation is in perfect condition. If the insulation has become brittle or has developed cracks, or if a failure exists between phases or turns of the winding, these effects will not normally be reflected in variations of the insulation resistance to ground. In some instances high resistance values may be noted despite the presence of punctures in the insulation. Insulation resistance measurements should always be supplemented by a thorough visual inspection of the insulation, and in some instances additional testing, before arriving at conclusions relative to the conditions of the insulation.

300-3.4.2 MEASUREMENT PERIODICITY. Insulation resistance measurements of generators and motors should be made periodically at the intervals prescribed by the PMS system or as amplified in paragraphs 300-4.7.19 through 300-4.7.19.6. For measurements in interior communication and fire control circuits, see **NSTM Chapter 430, Interior Communication Installation.**

300-3.4.2.1 Warm Machines. When measuring the insulation resistance of warm machines, measurements should be taken immediately after shutdown when the machine is still hot. When machines are operated at overloads or are exposed to moisture, water, salt spray, dust, or when consistently low values of resistance are obtained, tests should be made more frequently. In addition to measurements taken when the machine is hot, tests may also be taken occasionally when the machine is idle and at room temperature. Measurements taken when the machine is cold furnish data concerning the effects of moisture and temperature on the insulation resistance of a machine.

300-3.4.2.1.1 Readings at room temperature are also needed for checking insulation resistance of stored parts such as armatures and field coils and for checking complete machines which are being stored or which have not been operated for appreciable lengths of time.

300-3.4.2.2 Cold Machines. Cold tests taken prior to placing a machine in service are especially valuable for determining whether the insulation is suitable after long periods of idleness or after exposure to excessively humid or dirty conditions, or to water or shock. Insulation resistance tests should also be taken after a machine has been repaired or serviced and on all new machines before they are placed in service, and prior to and after dielectric tests.

300-3.4.2.3 Installed Voltmeters. Where permanently installed ground detector voltmeters are provided, the readings indicated by the voltmeter should be observed at least once each watch if the circuit is energized. The ground detector voltmeter is, of course, not capable of being used when the circuit is not energized.

Table 300-3-4 DC GENERATORS AND MOTORS (EXCEPT PROPULSION AND AUXILIARY GENERATORS FOR SUBMARINES) INCLUDING EXCITERS

Circuit	Insulation Resistance (megohms at 25°C)[1]			
	Minimum for Operation	**After Cleaning in Ship**	**After Reconditioning**	**After Rewinding**
Complete armature circuit[2]	0.1	0.5	1.0	100
Armature alone	0.2	1.0	2.0	200
Armature circuit less armature[2]	0.2	1.0	2.0	200
Complete field circuit	0.5	1.5	2.5	200

NOTES:
1. Values are for machines rated 250 volts or less. For machines having a rated voltage (E) greater than 250 volts, multiply all values given in the table by E/250.
2. Small machines usually have one of the shunt field leads connected internally to the armature circuit. To avoid disassembly in such cases, the complete armature circuit and the complete field circuit may be measured without breaking this connection. If necessary, the armature can be isolated by lifting the brushes.
a. With brushes left in place, the complete armature circuit will include armature, armature circuit, and the permanent connected field circuit. The values given in the table for the complete armature circuit will apply.
b. With brushes lifted, the armature circuit, less armature and the complete field circuit will be measured. The values given in the table for armature circuit, less armature will apply.

300-3.4.3 ISOLATING THE MACHINE. When the insulation resistance drops below the levels allowed in paragraph 300-4.7.19.2 or there is a significant drop from previous after cleaning values, further investigation is necessary. This is accomplished by separating portions of the circuit until the cause is determined and the problem corrected. For preliminary measurements, it is usually not essential to isolate the machine completely if isolation cannot be readily accomplished. Disconnect as much of the connecting cable and associated equipment as is practical by opening line switches, circuit breakers, and contactors. The insulation resistance measurements taken in this manner will include the effect of the cable and equipment which is still connected. If the value of insulation resistance is lower than judged to be satisfactory, the machine must be further isolated by disconnecting the cable at the machine and repeating the tests. If the insulation resistance of the circuit within the machine still measures too low, the internal connections should be disconnected, proceeding progressively to measure the insulation resistance of individual windings, coils, and so forth, until the low resistance portion is located. Shunt field circuits may be broken up by disconnecting the leads connecting successive poles. Armature windings may be isolated by lifting all the brushes off the commutator. Phase windings may be isolated from each other where terminals for both ends of each phase are provided. Brush holder stud insulation may be measured separately when the brushes are lifted and the connections to the bus rings broken.

300-3.4.4 CIRCUIT ISOLATION CONSIDERATIONS. Breaking the circuit up into its component parts may not be necessary if the low insulation resistance is suspected to be due to some general unsatisfactory overall condition, such as excessive moisture in the insulation, condensation on its surfaces, or accumulations of foreign matter. In such cases corrective steps may be taken and further tests made to determine whether the insulation resistance has been improved without breaking the internal connections within the machine.

300-3.4.5 CIRCUITS TO BE MEASURED. When the insulation resistance levels are below the levels allowed in paragraph 300-4.7.19.2, or there is a significant drop from previous after-cleaning values, the machine circuits should be measured separately as described in the following paragraphs.

300-3.4.5.1 DC and AC Machines. For dc machines, the shunt field circuit and the armature circuit (including interpoles, series fields, brushes, and brush rigging insulation) should be tested separately except in the case of small size machines which may have one of the shunt field leads connected internally to the armature circuit. For ac machines, the armature winding and field winding should be tested separately in all cases. When measurements are being made on one winding, all other windings should be connected to ground.

300-3.4.5.2 Applying Test Voltage. All measurements should be made with the test voltage applied between the copper conductors and the metallic structure in which the winding is embedded. If necessary, a good connection should be assured by removing paint or any corrosion at the point of contact on this structural part. Any bare copper surface or terminal will be suitable for making the copper contact.

300-3.4.5.2.1 When testing rotor windings, the test voltage should be applied between the copper conductors and a metallic part of the rotor rather than the stator in order to eliminate the insulating effect of oil in the bearings.

Table 300-3-5 DC PROPULSION GENERATORS AND MOTORS AND DC AUXILIARY GENERATORS FOR SUBMARINES

	Insulation Resistance (megohms at 25°C)[1]				
Circuit	**Minimum for Operation**	**After Cleaning in Ship**	**After Reconditioning in Place**	**After Reconditioning in Shop**	**After Rewinding**
Complete armature circuit	R x 0.5	R x 1.5	R x 25	R x 30	R x 100
Armature alone	R x 0.5	R x 2.5	R x 40	R x 50	R x 1000
Armature circuit less armature	R x 0.5	R x 2.5	R x 40	R x 50	R x 1000
Complete field circuit	R x 2.0	R x 5.0	R x 90	R x 100	R x 2000

Where:

$$R = E \,/\, \left(\frac{kW}{100} + 1{,}000\right)$$

E = rated voltage of generator or motor
kW = kilowatt rating of generator or motor. Motor kilowatt rating equals rated horsepower (HP) x 0.746

300-3.4.5.3 Portable Equipment. For portable tools, appliances, and cable assemblies, measure the insulation resistance of each line terminal to the equipment frame and to the metal shell of the equipment plug.

300-3.4.6 RECORDS. Records of the insulation resistance measurements taken on electrical machinery should be maintained in accordance with the requirements of the ships 3-M System, see paragraphs 300-4.2.3 and 300-4.2.3.1. Data can also be recorded in the applicable Work Center Log.

300-3.4.6.1 Data Example. The following data may be recorded as necessary:

a. Date

b. Machine or circuit identification

c. Value of armature insulation resistance between conductors and ground

Table 300-3-6 AC GENERATORS AND MOTORS OTHER THAN PROPULSION

Circuit	Insulation Resistance (megohms at 25°C)[1]			
	Minimum for Operation	**After Cleaning in Ship**	**After Reconditioning**	**New Winding or After Rewinding**
Stator circuit of generators and motors	0.2	1.0	25	200
Rotor circuit of wound rotor induction motors	0.1	0.5	25	100
Field circuit of generators or of synchronous motors	0.4	2.0	25	400
Stator circuit of motors with sealed insulation system	2.0	25	500	1000[2] 100[3]

NOTES:
1. Values are for machines rated 500 volts or less. For machines having a rated voltage (E) greater than 500 volts, multiply all values given in the table by E/500.
2. Minimum acceptable value with winding dry, before and after submergence test.
3. Minimum acceptable value during 24-hour freshwater submergence test

Table 300-3-7 AC PROPULSION GENERATORS AND MOTORS

Circuit	Insulation Resistance (megohms at 25°C)				
	Minimum for Operation	**After Cleaning in Ship**	**After Reconditioning in Place**	**After Reconditioning in Shop**	**After Rewinding**
Stator circuit of generators and motors	R x 0.4	R x 2.0	R x 30	R x 40	R x 100
Rotor circuit of wound rotor induction motors	R x 0.2	R x 1.0	R x 15	R x 20	R x 200
Field circuit of generators or of synchronous motors	0.4	2.0	30	40	R x 400

Where:

$$R = E / \left(\frac{kW}{100} + 1,000\right)$$

E = rated voltage of generator or motor
kW = kilowatt rating of generator or motor. Motor kilowatt rating equals rated horsepower (HP) x 0.746

Table 300-3-8 MOTOR GENERATORS FOR SUBMARINES

Component	Insulation Resistance (megohms at 25°C)					
	Minimum for Operation	**After Cleaning in Ship[1]**	**After Reconditioning in Place[2]**	**After Reconditioning in Shop[2,4]**	**After Reconditioning in Shop[5]**	**After Rewinding[6]**
DC complete armature circuit[3]	0.1	0.5	-	10	250	1000
DC armature alone	0.2	1.0	25	50	1000	2000
DC armature circuit less armature[3]	0.2	1.0	-	10	1000	1000
Complete field circuit[3]	0.5	1.25	-	10	100	1000
DC fields	0.5	1.25	25	50[3]	500[3,7]	2000
AC stator circuit of generators and motors	0.1	1.0	-	10	100	2000
AC rotor circuit of wound rotor induction motors	0.1	0.5	-	10	100	2000
Field circuit of generators or of synchronous motors	.04	2.0	-	10	100	2000
AC stator	0.2	1.0	25	50	1000	2000
AC field	0.1	0.5	10	50	1000	2000
Regulator and controls (wound components)	0.2	1.0	-	25	100	200

Table 300-3-8 MOTOR GENERATORS FOR SUBMARINES - Continued

Component	Insulation Resistance (megohms at 25°C)					
	Minimum for Operation	After Cleaning in Ship[1]	After Reconditioning in Place[2]	After Reconditioning in Shop[2,4]	After Reconditioning in Shop[5]	After Rewinding[6]

NOTES:
1. Use hand-cleaning (wiping) methods, vacuum, blower, water spray or solvents (see paragraphs 300-4.5.2 through 300-4.5.5).
2. Also to be before varnishing criteria for wound components reconditioned.
3. Machines usually have one of the shunt communicating or series field leads connected internally to the armature circuit. To avoid disassembly in such cases, the complete armature circuit may be measured without breaking these connections. If necessary, the armature can then be isolated by lifting all brushes.
a. With brushes left in place, the complete armature circuit will include armature, armature circuit and the permanently connected field circuit. The values given in the table for the complete armature circuit will apply.
b. With brushes lifted, the armature circuit, less armature and the complete field circuit will be measure. The values given in the table for armature circuit less armature will apply.
4. Criteria, for MG components reconditioned by IMA activities. Applicable to both standard dip and bake and VPI insulation systems. Not applicable as criteria for overhaul of MG components having VPI insulation systems.
5. This criteria applicable only to AERP, non-AERP and TRIPER MG sets having certified VPI insulation systems that are being reconditioned as part of planned overhaul. Reconditioning shall include cleaning and drying followed by one VPI process using NAVSEA approved and certified procedures or one dip and bake treatment dependent upon the repair activities facilities and capabilities.
6. The rewinding of all components except wound components of regulators and control units utilizes vacuum pressure impregnation using solventless epoxy resin; hence, higher values for these components.
7. DC fields should maintain a minimum of 2 megohms when measured at 130°C.

d. Value of field winding insulation resistance between conductors and ground

e. Amount of cable or other equipment connected to machine under test

f. Actual or estimated temperature of winding under test

g. History of conditions preceding test such as load, temperatures of windings and ventilating air, room temperature, and humidity, weather conditions over past few days, and so forth.

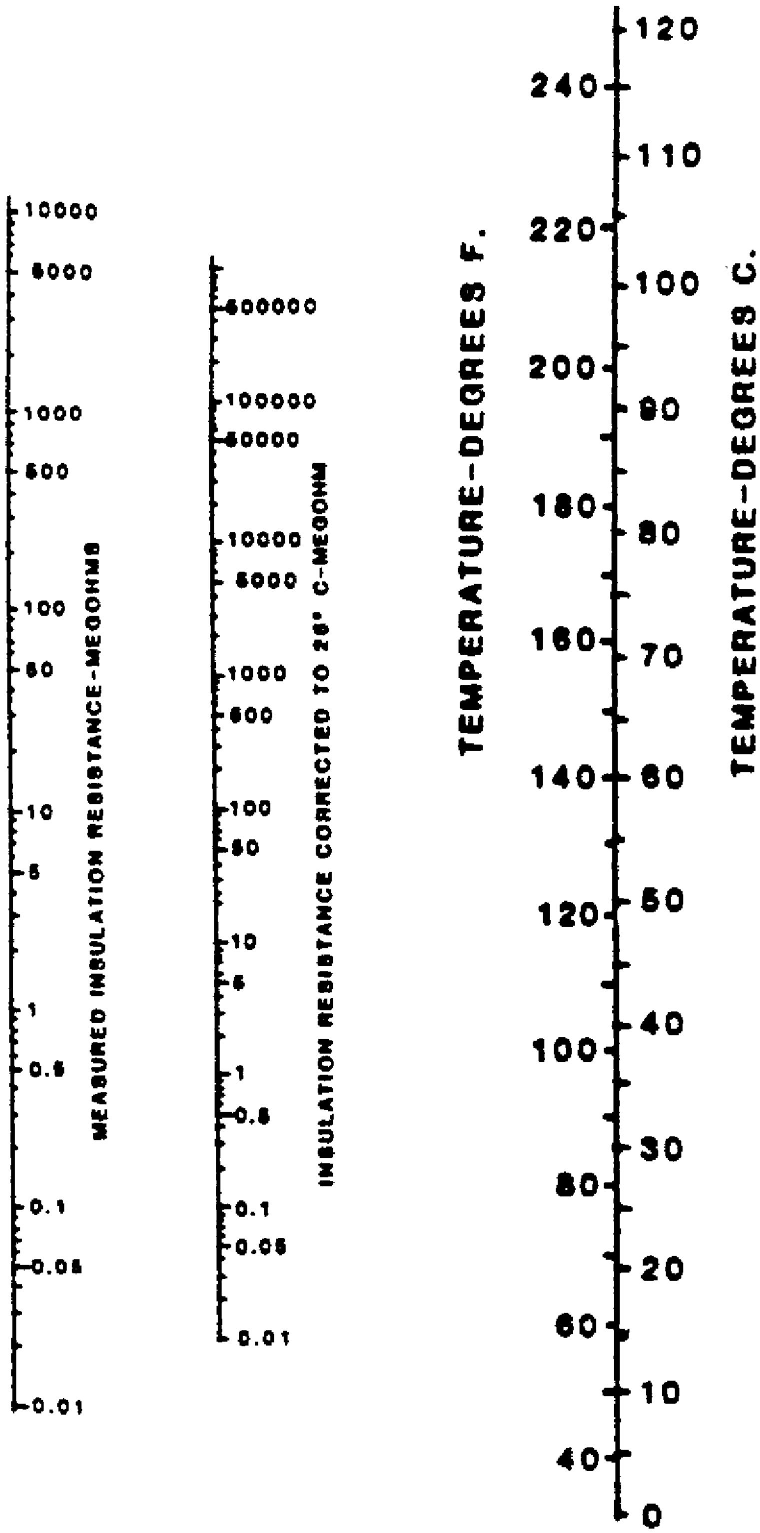


Figure 300-3-9 Insulation Resistance - Temperature Nomograph

300-3.4.6.2 Insulation Resistance Curve. Curves showing the value of insulation resistance plotted against time are particularly useful for showing trend of insulation resistance values. Figure 300-3-10 shows the general trend which may be obtained over a period of time for large dc motors and generators. If records are to be kept, a new curve should be started for each machine every time the machine is given a thorough cleaning by yard, base, or tender force, or after each yard, base, or tender overhaul. It should be noted that the ordinates of Figure 300-3-10 are plotted with a logarithmic scale.

300-3.4.7 INTERPRETING MEASUREMENTS. When the insulation resistance level of a machine falls below that allowed in paragraph 300-4.7.19.2, or there is a significant drop from previous after-cleaning values, it is necessary to interpret the meaning of these new levels. The following conclusions based on practical service experience should be of assistance in understanding what values and variations in insulation resistance may be considered normal and abnormal in deciding what corrective measures should be taken when abnormal conditions are encountered.

300-3.4.7.1 Normal Degradation. After the period of time required for the varnish to dry has elapsed, the insulation resistance of a winding or circuit in good condition may be expected to decrease gradually with age, if no variations in moisture content, temperature, or cleanliness occur (see paragraph 300-3.4.1.5.1).

300-3.4.7.2 Periodic Measurements. Periodic tests in service are useful in detecting weaknesses of insulation or accumulations of moisture or dirt. Such conditions are usually indicated by marked decreases in insulation resistance. Hence, periodic measurements serve to determine when cleaning, drying, or other servicing of the machine is necessary.

300-3.4.7.3 Inspections. A high value of insulation resistance is not always proof that the insulation is in good condition (see paragraph 300-3.4.1.5.2). For this reason, complete and thorough inspections should be made regularly in addition to the periodic tests of insulation resistance.

300-3.4.7.4 Instrument Response. When measuring resistance, if the instrument pointer requires appreciable time to reach a steady value, the insulation is usually relatively dry and clean. If the instrument pointer becomes steady quickly and the resistance is low, there is a strong possibility that the insulation is moist, dirty, or damaged.

300-3.4.8 MINIMUM VALUES. When the insulation resistance level of a machine falls below that allowed in Table 300-3-4, Table 300-3-5, Table 300-3-6, Table 300-3-7, and Table 300-3-8 or there is a significant drop from previous after-cleaning values, tests of subcircuits are performed. The allowable levels of the subcircuits are somewhat different and are also tabulated in Table 300-3-4, Table 300-3-5, Table 300-3-6, Table 300-3-7, and Table 300-3-8. It is impossible to set a rigidly fixed value for the minimum permissible insulation resistance on a machine and state positively that if the machine has an insulation resistance below the minimum value, it will fail; or that if it has an insulation resistance above the minimum value, it will operate satisfactorily. Machines can and have operated satisfactorily over extended periods of time with low insulation resistance. Conversely, a high value of insulation resistance alone is not sufficient to ensure satisfactory operation. Nevertheless, despite those limitations, past experience has made it possible to set up limiting values of insulation resistance which serve to indicate the values that should be maintained on machines in service, and also serve to determine the nature of the treatment that should be given electrical equipment when it is overhauled.

300-3.4.9 EXPLANATION OF TABLES. Table 300-3-4, Table 300-3-5, Table 300-3-6, Table 300-3-7, and Table 300-3-8 list insulation resistance levels of the isolated machine or circuit. The tables present insulation resistance values for five types of machines. For each machine, several sets of insulation resistance values are given as applicable: minimum for operating, after cleaning in ship, after reconditioning in place, after reconditioning in shop and after rewinding. The information in the following paragraphs is pertinent to use of the tables. Reconditioning means cleaning and revarnishing.

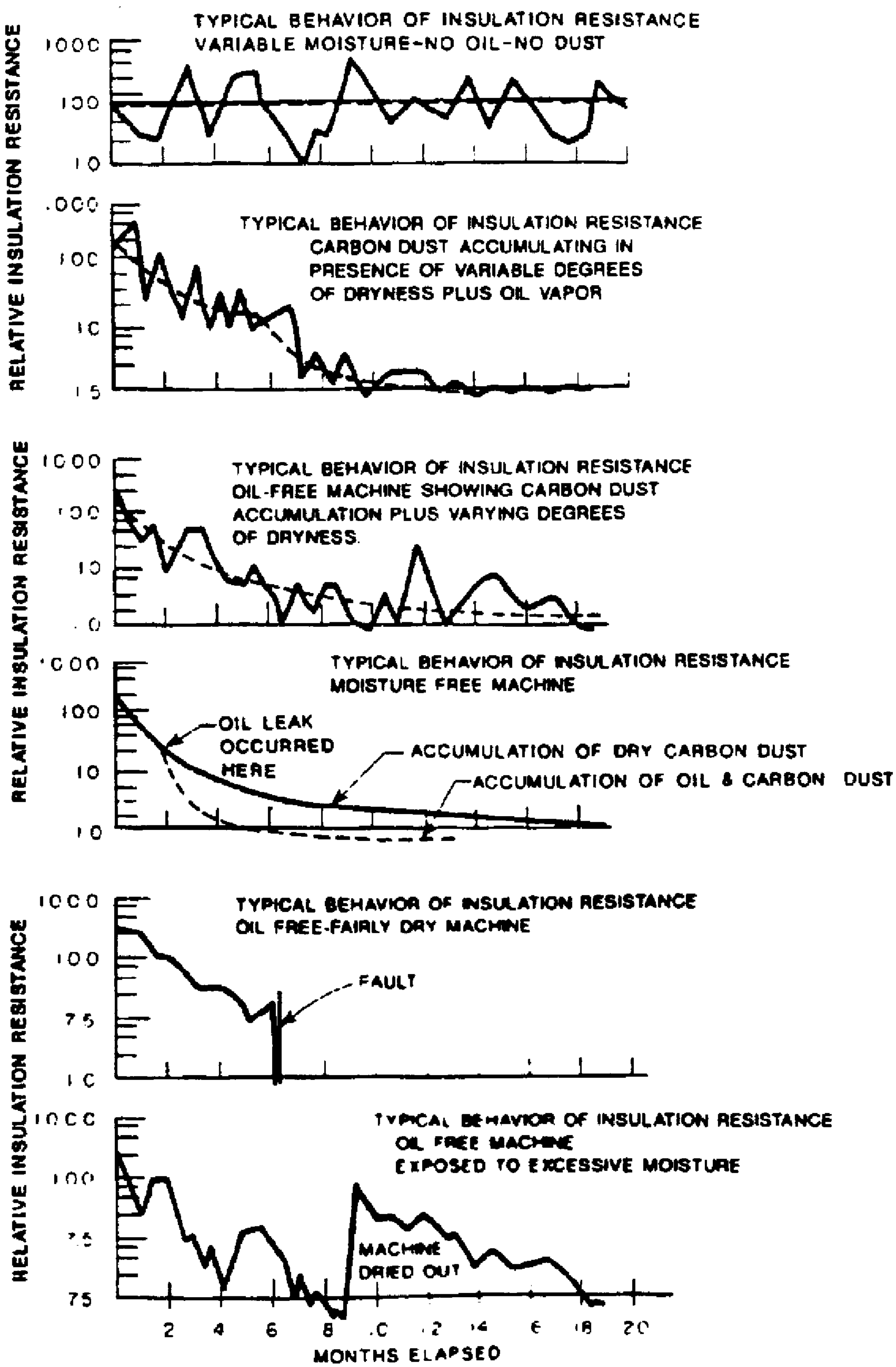


Figure 300-3-10 Logarithmic Plot of Insulation Resistance Versus Time

300-3.4.9.1 Temperature Correction. Insulation resistance values in Table 300-3-4 through Table 300-3-8 are based on a winding temperature of 25°C (77°F). When using these tables to evaluate values of measured insulation resistance, the measured values should be temperature corrected to 25°C (77°F) using the nomograph of Figure 300-3-9 (see paragraph 300-3.4.1.3).

300-3.4.9.2 Minimum Values. All figures are minimum values. Insulation resistances well above the minimum values are normally obtainable. Every reasonable effort should be made to maintain insulation resistances at values considerably higher than those given in the tables.

300-3.4.9.3 Armature Circuit. The complete armature circuit of a dc machine includes the armature, brush rigging, connections to machine terminals, and any fields which carry armature current, such as commutating field, compensating field, and series field.

300-3.4.9.4 Stator Circuit. The stator circuit of polyphase generators and motors and the rotor circuit of wound rotor induction motors includes all phases. When a single phase is isolated (see paragraphs 300-3.4.3 through 300-3.4.4), its insulation resistance should be at least three times the value given in Table 300-3-6 or Table 300-3-7 if the machine has three phases, or at least two times if the machine has two phases (used in some electric propulsion equipment).

300-3.4.9.5 Cleaning Definition. The word cleaning as used in the tables includes thorough cleaning of the machine and such maintenance as drying the machine by means of external heat, by energizing the windings or by the use of a desiccant and does not include such minor maintenance as wiping commutators or slip rings.

300-3.4.10 INSULATION RESISTANCE OF MACHINES IN SERVICE. Table 300-3-4, Table 300-3-5, Table 300-3-6, Table 300-3-7, and Table 300-3-8 list minimum allowable insulation resistance levels of the isolated machine or circuit under various conditions. The data listed in the Minimum for Operation columns of the tables represent insulation resistance values at, or below which, machines should be removed from service and thoroughly cleaned, dried out, or repaired as necessary.

300-3.4.10.1 Exposure to Excessive Moisture and Dirt. If the machine has been exposed to excessive moisture, has been splashed with water, or has been shut down for a long period, the insulation should be dried out. If the machine has been exposed to excessive dust or dirt, as when the commutator is stoned or the brushes seated, or if a visual inspection indicates that the machine is in a dirty condition, the need for cleaning the machine is evident. Frequently visual inspection will reveal physical damage that has occurred and caused abnormal measurements to be obtained.

300-3.4.10.2 Abnormal Condition Unknown. If the cause of the abnormal condition cannot be readily determined as noted above, insulation resistance measurements should be taken on the component parts of the circuits within the machine, including, if necessary, individual field coils, internal leads, brush holder insulation, collector rings, and so forth. Often a defective lead or deposits of dirt on exposed terminals or brush insulation are the cause of low insulation resistance to ground. In such cases, the defective part should be thoroughly cleaned and its insulation resistance checked again.

300-3.4.10.2.1 If the trouble cannot be located by following the (foregoing) procedure, inspect the end windings for accumulation of dirt, dust, or other foreign matter and for signs of damage.

300-3.4.10.2.2 If the trouble cannot be localized, the machine should be dried out, thoroughly cleaned, and carefully inspected to check the condition of the entire machine.

300-3.4.10.2.3 If the machine still has an insulation resistance which is below the value given in the After Cleaning in Ship column of the applicable table, the trouble is probably due to a general or local weakness of the insulation. Unless the insulation resistance is below the value given in the Minimum for Operation column of the applicable table, the machine may be placed in service but should be checked every few days. If the insulation resistance remains low for a continued period, the machine should be taken out of service for repair and overhaul. If the insulation resistance is below the value given in the Minimum for Operation column of the applicable table, the machine should not be used, except in case of emergency, until it can be reconditioned by shipyard or base forces.

300-3.4.10.2.4 Values less than those given in the Minimum for Operation columns should not be construed as necessarily indicating an unsafe condition or one which would prohibit the use of a machine if necessary. However, when values less than those are obtained for a machine, use of the machines should be avoided if practical and action should be taken at first opportunity to find and remedy the cause of the low insulation resistance. The cause of abnormally low insulation resistance may be the nature of the operating conditions prior to the test which showed low insulation resistance.

300-3.4.11 INSULATION RESISTANCE AS A GUIDE IN OVERHAUL. When the machine circuits have been isolated because the levels are below those allowed by paragraphs 300-4.7.19 through 300-4.7.19.6 , the decision to initiate corrective action shall be based on guidelines provided herein. Insulation resistance measurements serve as useful guides to determine the nature and amount of work that should be done in the overhaul of electric equipment. The following instructions apply except for complete overhaul of electric propulsion equipment which shall be made at periodic intervals as prescribed in **NSTM Chapter 235, Electric Propulsion Installations.**

1. Select the applicable table from Table 300-3-4, Table 300-3-5, Table 300-3-6, Table 300-3-7, and Table 300-3-8 for the machine under consideration.
2. Before cleaning the machine or doing any overhaul work, measure the insulation resistance of the largest circuits listed in the applicable table. These will be the complete armature circuit and the complete field circuit for dc machines, the stator circuit and field circuit for ac generators, and so forth.
3. If the insulation resistance of the circuit is less than the value given in the Minimum for Operation column of the applicable table, break the circuit up into its component parts and measure their insulation resistances to locate the part or parts responsible for the low insulation resistance. Remove these parts (or all parts of the circuit if the trouble cannot be traced to specific parts) to a shop for a thorough reconditioning. Clean the remaining parts in the machine.
4. If the insulation resistance of a circuit before cleaning is greater than the value given in the Minimum for Operation column of the applicable table, clean the circuit in the machine without disassembly except for removal of access plates.
5. If the insulation resistance after cleaning is greater than the value given in the After Cleaning in Ship column of the table, and if visual inspection gives no evidence of defects, the circuit is suitable for service.
6. If the insulation resistance after cleaning is less than the value given in the After Cleaning in Ship column of the applicable table, break up the circuit into its component parts and measure their insulation resistance to locate those responsible for the low insulation resistance. Remove these parts to a shop for a thorough reconditioning. If the trouble cannot be traced to any specific parts, repeat the cleaning of the entire circuit in the

machine. If the insulation resistance is still less than the value given in the After Cleaning in Ship column of the table, the entire circuit should be thoroughly reconditioned in a shop.

7. The insulation resistance of a circuit or winding which has been reconditioned in a shop should be greater than the value given in the After Reconditioning in Shop column of the applicable table.

8. Circuits and windings which have been replaced (rewound) in a shop and which have insulation resistance in accordance with subparagraph 7, should be given a high potential test (see paragraph 300-3.5.3) by the shop which has done the rewinding, provided the shop is equipped with high potential test facilities. A high-potential test should not be made on circuits which have been cleaned in the machine or on any winding in which the insulation resistance is less than that given in the After Reconditioning in Shop column of the applicable table.

300-3.4.11.1 The following example shows how insulation resistance can be used as a guide in overhauling a generator:

1. Assume that a submarine becomes available at a naval shipyard or other overhaul activity and that the cleaning (not the complete overhaul) of a propulsion generator is to be undertaken. Since the machine is a dc propulsion generator, Table 300-3-5 is applicable. The rating of the generator is 415 volts, 1,100 kilowatts. The temperature of the generator is 25°C (77°F) and the machine is dry. Substituting values in applicable formula and table gives:

$$\mathbf{R} = 415 + \left[\frac{1,000}{100} + 1,000\right]$$
$$= 0.41 \text{ megohm}$$

Figure 1.

2. Complete armature circuit. Assume that the following conditions prevail:
   a Measured value of insulation resistance of complete armature circuit is 0.16 megohm. This value is greater than 0.12 megohm, the value in the Minimum for Operation column of the table. The complete armature circuit is, therefore, cleaned in place.
   b After cleaning, the measured value of the insulation resistance of the complete armature circuit is 0.45 megohm which is less than 0.61 megohm, the value in the After Cleaning in Ship column.
   c The armature alone is disconnected from the complete armature circuit and the armature is measured alone, giving a value of 1.2 megohms which is greater than 1.0 megohm, the value in the After Cleaning in Ship column, indicating that the armature is satisfactory for service.
   d The measured value of insulation resistance of the armature circuit less armature is found to be 0.75 megohm which is less than 1.0 megohm, the value in the After Cleaning in Ship column, indicating that the armature circuit less armature needs additional cleaning or that there is some isolated low resistance path. The brush rigging, after being disconnected from the combined commutating and compensating winding by removing the flexible connector between them, is found to measure 5 megohms. The winding measures 0.8 megohms indicating a low resistance path to ground somewhere in the winding. The combined commutating and compensating winding is then disconnected pole by pole and each pole is measure separately. It is found that one commutating field pole has lower insulation resistance than any of the other commutating field poles. Upon further investigation it is found that one of the less accessible spots on the pole has not been adequately cleaned, and after this place is cleaned, the insulation resistance of the pole in question is measured and found to be equal to all of the other poles. All parts of the armature circuit less armature are then reconnected and the insulation resistance measured, giving a value of 1.8 megohms which is greater

than 1.0 megohm, indicating that these parts are satisfactory for service. The armature is then connected in the circuit and the complete armature circuit gives a measured insulation resistance value of 0.75 megohm which is greater than 0.61 megohm, and the complete armature circuit is ready for service.

3. Field Circuit. The measured value of insulation resistance of the complete field circuit before cleaning is 0.10 megohm which is less than 0.82 megohm, the value in the Minimum for Operation column. Each field coil is disconnected and tested separately and one coil is found to have much lower insulation resistance than any of the other coils. This coil is removed and it is found that the insulation between the coil and the metal pole piece has been damaged, allowing a low resistance path to ground. The damaged insulation is renewed and all of the field coils cleaned and reconnected. The insulation resistance then measures 3.5 megohms which indicates that the complete field circuits is ready for service.

300-3.4.12 POLARIZATION INDEX TEST. Polarization index (PI) is the ratio of the 10-minute insulation resistance value to the 1-minute insulation resistance value. The change in insulation resistance with the duration of the test potential application is useful in appraising the cleanliness and dryness of a winding. Insulation resistance of a winding will normally increase with the duration of the test voltage. The measured insulation resistance of a dry winding in good condition will reach a fairly steady value in 10 to 15 minutes. If the winding is wet or dirty, the steady value will usually be reached in 1 or 2 minutes. The slope of the curve is an indication of insulation condition. Figure 300-3-11 shows the polarization index of a typical armature winding. If the winding temperature has changed during the interval between the one and ten minute measurements, the values of the insulation resistance used to determine the PI must be temperature corrected. Temperature corrections should be made to 25°C using the nomograph in Figure 300-3-9.

The PI test may be used as a diagnostic tool at any point in the reconditioning or rewind process to identify the level of insulation contamination. The PI test should be used during incoming inspection. Used in conjunction with the one-minute insulation resistance test, motors that have absorbed moisture or other contaminants will be identified for reconditioning. Requirements applicable to the PI test are as follows:

a. The PI test should be performed at incoming inspection if the temperature corrected value of the one minute insulation resistance is greater than or equal to the ″Minimum for Operation″ and less than 5 times the applicable ″After Reconditioning″ value in Table 300-3-4 through Table 300-3-8.

b. An exception to ″a″ is for motors with a sealed insulation system. If the value of one-minute insulation resistance of a motor with sealed insulation is greater than or equal to the ″Minimum for Operation″ and less than 500 megohm, a PI test should be performed.

c. For most equipment, including induction motors, the minimum acceptable value of PI is 2.0. There are unique equipments that because of their construction cannot achieve values of PI as high as 2.0. Examples of such equipment are some exciters and DC armatures. The repair activity is responsible for establishing minimum values of PI for these equipments that cannot attain a PI of 2.0.

d. If the polarization index is unacceptable, the equipment should be reconditioned.

300-3.5 SEQUENCE OF ELECTRICAL TESTS

300-3.5.1 SEQUENCE TABLE. The sequence of electrical tests for both reconditioned windings and rewound equipment is shown in Table 300-3-9. By following this sequence of tests, problem areas may be discovered early enough in the processing and corrected without starting over.

CAUTION

DC high-potential testers can cause permanent damage to equipment insulation due to surface tracking and localized heating. Operator shall stop the test if an abrupt rise in the leakage current is obtained. Apply the voltage only long enough for the current to stabilize and for plotting the data.

300-3.5.2 DC HIGH-POTENTIAL TESTS. Dc high-potential tests are made by applying dc voltage in steps and recording leakage current (microamperes) through the insulation. The voltage and current are plotted on cross-sectional paper and the shape of the resultant curve is used for checking the cleanliness and moisture content of the machine tested.

300-3.5.2.1 Applicability. The dc high-potential test should be used during overhaul to determine cleanliness and moisture content of insulation before or during reconditioning of equipment, since it is less destructive than ac testing. The dc high-potential test can also be used at a reduced voltage as a preventive or troubleshooting technique. High-potential ac testing should be used as a final shop test on reconditioned or new equipment to detect faulty insulation.

300-3.5.2.2 Test Equipment. The following test equipment and procedures for testing are applicable:

a. The tester should be able to vary voltage smoothly from zero up to maximum required.

b. The microammeter should have sufficient ranges to provide readings from less than 1 to at least 2,500 microamperes.

c. A maximum voltage of not less than 5,000 is recommended for at least one tester at each activity.

d. Each activity should have at least two testers. One should be small enough to be carried through ship hatches.

e. Tester should be provided with a protective current relay which can be set to trip at any given percentage of the microammeter scale. This is to prevent insulation failure when the leakage current rises sharply.

f. Direct current high-voltage testers are available from (among others) the following: James G. Biddle Company
   Plymouth Meeting, PA
   19462 Model 220005-PR
   Associated Research, Inc.
   3780 W. Belmont Street
   Chicago, IL
   60618 HYPOT Model 424

300-3.5.2.3 Test Procedure Instructions. Before conducting the high-potential test, discharge the windings to ground as specified in paragraph 300-3.5.2. The maximum dc high potential test voltage, applied to equipment, shall not exceed 1.6 times the applicable ac high-potential test voltage of Table 300-3-10 for rewound or non-rewound windings. To perform the dc high-potential tests, attach the positive terminal of the tester to the copper and the negative terminal to the iron.

CAUTION

Do not allow the overcurrent relay to trip. Tripping the overcurrent relay produces an inductive voltage surge that could damage the insulation. Increase the test voltage slowly enough to see an abrupt rise in the slope of the leakage current curve and to stop the test.

300-3.5.2.3.1 Plot a curve of the measured leakage current values taking at least eight equally spaced voltage points up to full voltage. Select the curve scale to suit the leakage current being obtained. On some machines, this will be less than 1 microampere. On others, it will be in milliamperes. Record the data for each point after the current stabilizes (possibly several minutes on large machines). Use the curve shown in Figure 300-3-12 as guidance. Approximately 25 percent of the calculated maximum test voltage or 500 volts, whichever is less, should be applied as the initial test voltage and the leakage current recorded. The current relay should then be set based on the estimated leakage current at maximum test voltage as follows:

$$I_{setting} = \frac{E_{max}}{E_{initial}} \times I_{initial}$$

The current relay may be adjusted upward slightly for gradually rising current to prevent it from tripping when the test is near the maximum voltage. Record the machine temperature once during the test.

Table 300-3-9 SEQUENCE OF ELECTRICAL TESTS ([1])

Component	When Conducted	Test
Commutator, rebuilt	Preinstallation (receipt from manufacturer) Postinstallation	ac high potential to ground (3500V) ac bar-to-bar (250V) ac high potential to ground (3500V) ac bar-to-bar (250V)
AC Stator, AC Fields, Exciter Rotor, Exciter Fields	Before and after interconnecting coils, prior to varnish treatment After varnish treatments (final acceptance tests)	Insulation resistance dc resistance Surge comparison dc high potential Insulation resistance dc resistance Surge comparison (except ac fields) ac high potential insulation resistance
DC Armatures	After winding (before connecting coils to risers) After connecting coils to risers but before any varnish treatments	Insulation resistance dc resistance Surge comparison dc high potential Insulation resistance dc resistance dc bar-to-bar Surge comparison dc high potential

Table 300-3-9 SEQUENCE OF ELECTRICAL TESTS ([1]) - Continued

Component	When Conducted	Test
	After varnish treatments (final acceptance tests)	Insulation resistance dc resistance dc bar-to-bar Surge comparison ac high potential Insulation resistance

NOTE:
1. For reconditioned components, the tests are run after cleaning and drying but before varnishing and again after varnishing. The test values for dc and ac high-potential and surge testing are 2/3 of the values used on rewound equipment, see Table 300-3-10.

300-3.5.2.3.2 When the dc high-potential test is used as either a preventative or troubleshooting maintenance action, conduct a megger test at 500 volts (or as recommended by the equipment technical manual) before each high-potential test and after the last high-potential test is completed. Record the megger reading on the curve sheet. An insulation resistance test need not be conducted by repair activities following the dc high-potential tests conducted during the refurbishment process because a megger test will be conducted as the initial test in each series of electrical tests that follow. After performing the megger and dc high-potential tests, ground the copper for a sufficient time to completely discharge the motor or generator. Following a dc high-potential test, hold the ground for at least four times the accumulated test period or 1 hour, whichever is longer. See paragraph 300-3.2.8.3 concerning residual charge. Failure to completely discharge the machine being tested will produce inaccurate megger readings taken after dc high potential test.

300-3.5.2.3.3 Direct current high-potential curves should be obtained before starting overhaul and after each major step in the overhaul procedure. In this manner improvements can be noted as the work progresses.

300-3.5.2.3.4 A typical set of curves for a large 1,000-kW, 415V, diesel-driven generator is shown in Figure 300-3-13. On large rotating equipment such as submarine and surface ship propulsion motors and generators, a flat low leakage line as illustrated (less than 10 microamperes) should be obtained before reinstallation in the ship. For example, even though a generator showed 150 megohms after a second cleaning and drying, an additional period in the drying oven removed the hook and lowered the whole curve. For smaller and less important units the cleaning and drying work may be stopped after the second cleaning and drying step.

CAUTION

Perform a 500 volt megger test before the high-potential test.

Table 300-3-10 VOLTAGE FOR AC HIGH POTENTIAL TESTS ON GENERATORS AND MOTORS*

	Circuits which have been reconditioned but not rewound or replaced, hence, not restored to a condition which should be as good as new			**Circuits which have been rewound or replaced, hence, restored to a condition which should be as good as new**		
	Armature Circuits of AC and DC Machines	**Field and Exciter Rotor and Rotor Circuits of AC Machines**	**Shunt, Series and Commutating Circuits of DC Machines**	**Armature Circuits of AC and DC Machines**	**Field and Exciter Rotor and Rotor Circuits of AC Machines**	**Shunt, Series and Commutating Circuits of DC Machines**
Generators, exciters and motors, including propulsion generators and motors, but excluding all machines listed below.	2/3 (2E + 1,000)	7V but in no case less than 1,000 volts nor more than 2,300 volts	2/3 (2V + 1,000)	2E + 1,000	10V but in no case less than 1,500 volts nor more than 3,500 volts	2V + 1,000
Generators and motors of not more than 250 volts and not more than 0.25 kilowatts (generators) or 0.5 horsepower (motors), except machines listed below.	600	600	600	900	900	900
Bracket fan motors.	400	400	600	600		
Generators and motors of not more than 35 volts except engine starting motors.	350	350	350	500	500	500
Engine starting motors not more than 36 volts.	500	500	750	750		
Generators and motors which have been temporarily reconditioned after submergence.	(See paragraph 300-5.5 through 300-5.6.2.1)					
NOTE: If one pole piece is defective, test all pole pieces to determine the extent of damage. If necessary, replace all pole pieces. E represents the rated voltage of the machine. V represents the operating voltage of the winding. Calculated values should be rounded to the next higher hundreds of volts.						

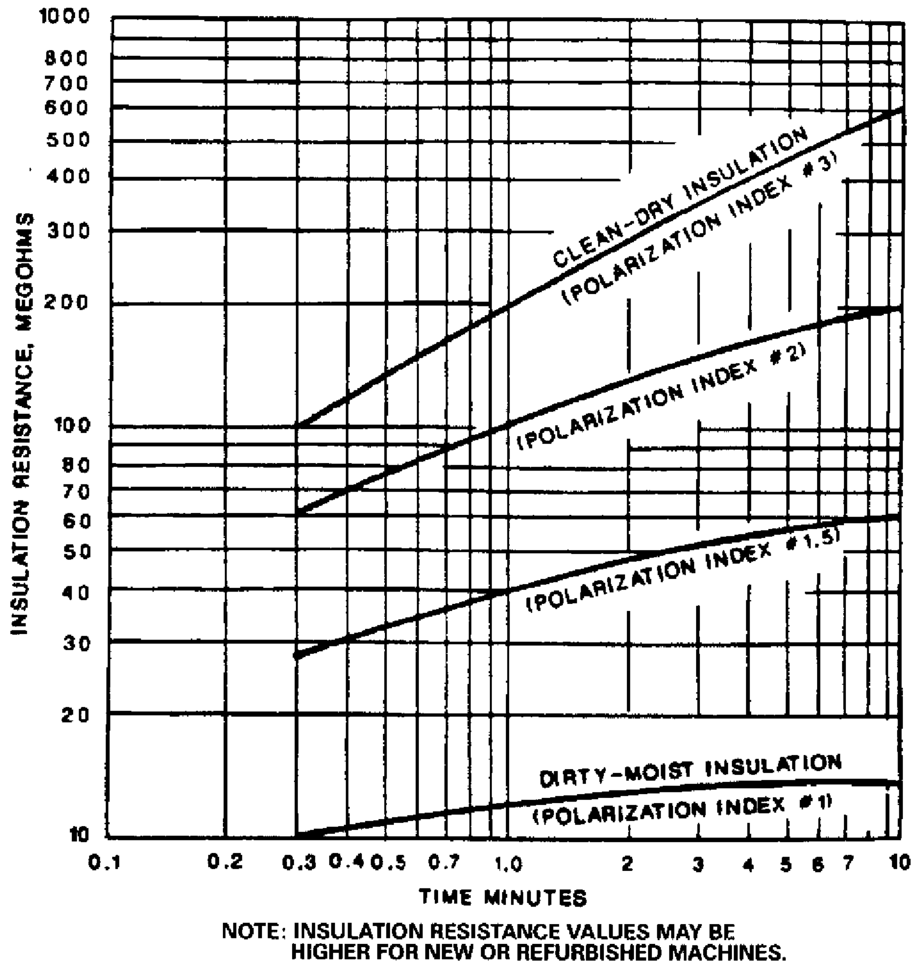


Figure 300-3-11 Variations in Insulation Resistance with Time for a Typical Winding

300-3.5.3 AC HIGH-POTENTIAL TESTS. A high-potential (hipot) test is made by applying a test potential which is higher than the rated operating voltage between insulated parts and insulated parts and ground. Motors, generators, and control equipment that have been reconditioned or rewound at a shore repair facility, tender, or repair ship should be given a final ac high-potential test to detect defective insulation. This test should be conducted before reinstalling equipment aboard ship. Care should be taken to insure that components that may be damaged by the high-potential test are disconnected or shunted out of the high voltage test circuit.

300-3.5.3.1 Applicability. High-potential tests are frequently used in connection with manufacture, repair, or reconditioning naval equipment ashore but should not be used for routine testing aboard ship for the following reasons:

a. The intent of the test is to break down the insulation if it is weak, thereby indicating defective material and workmanship and permitting replacement prior to actual use. Such a test, if made on apparatus installed in the ship, might result in failure, necessitating expensive repairs which the ship is not prepared to undertake; whereas, if the test were not made, the equipment would probably continue to function satisfactorily.

b. The application of each high-potential test tends to weaken insulation even though it does not produce actual failure at the time.

c. The use of high-potential test requires special equipment and safety precautions which are usually not practical for routine shipboard use.

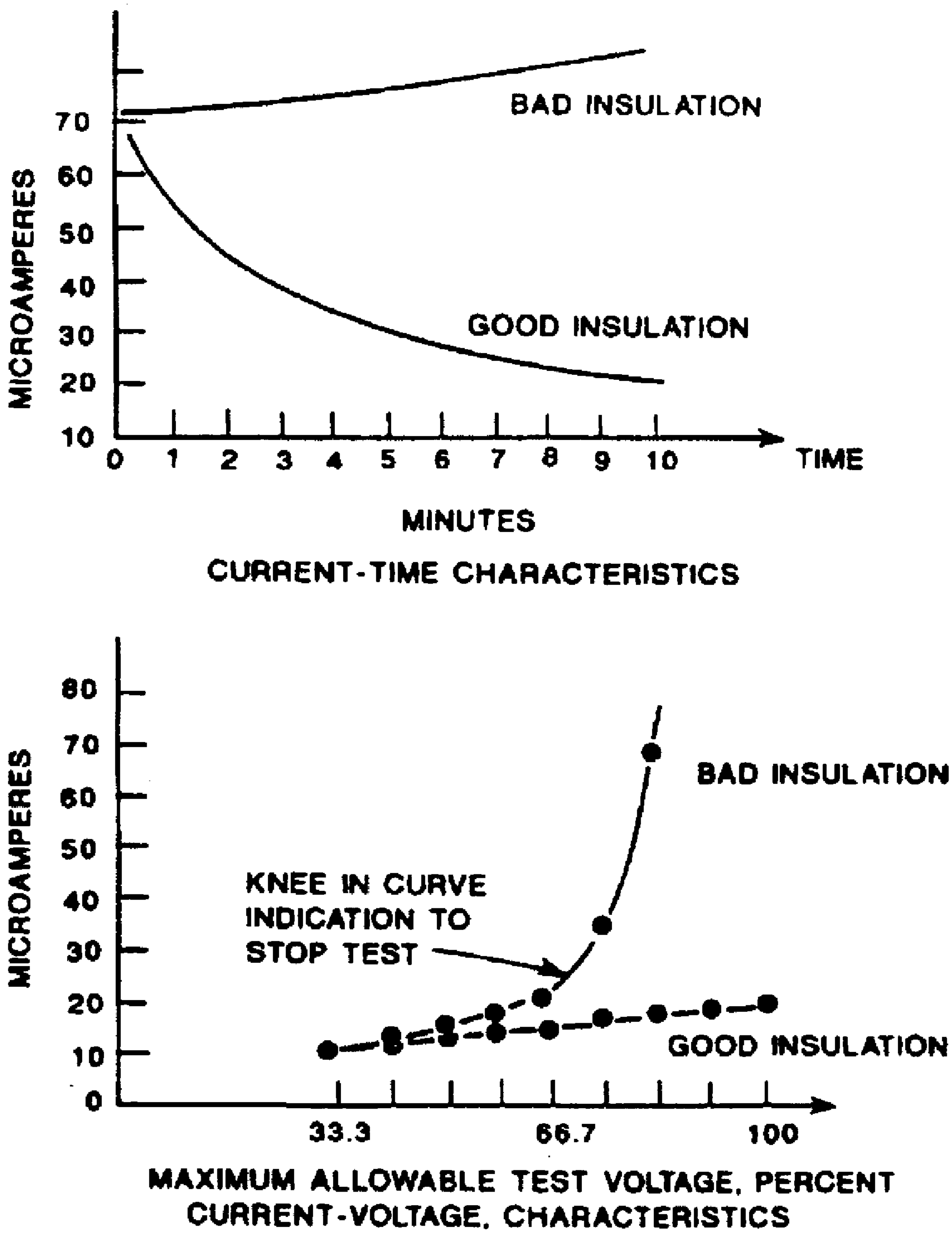


Figure 300-3-12 DC High-Potential Test Curves

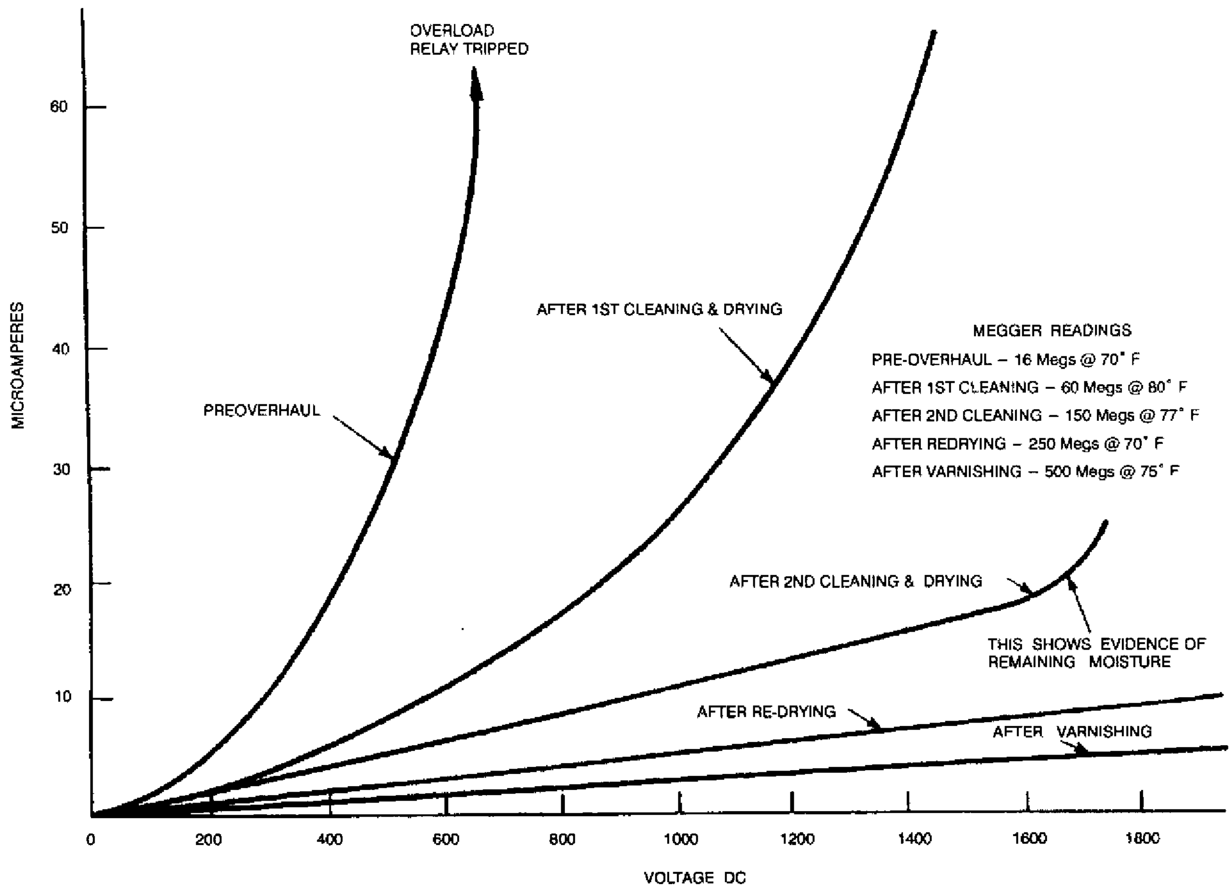


Figure 300-3-13 Typical DC High Potential Test Curves (1,000-kW, 415-Vdc Generator)

300-3.5.3.2 Procedure. The instructions contained in the following paragraphs apply to making high-potential tests on electrical equipment which has been reconditioned or rewound in a shop.

300-3.5.3.2.1 Keep everyone from coming in contact with any part of the circuit or apparatus while the test is being made. After a high-potential test has been made, never touch the winding tested until it has been connected to ground to remove any static charge it may have retained.

300-3.5.3.2.2 An ac high-potential test should only be made on generator or motor windings that are clean and dry. On rewinds, the ac test should be made only after all varnish treatments have been completed. On reconditioned windings (i.e., those windings only cleaned and revarnished) the ac test should also be made after varnishing is complete and at a reduced value of voltage; however, if the windings are smooth and glossy and the original varnish coat seems adequate and without craze marks, additional varnishing may not be necessary. In such cases, the ac hipot test should also be at a reduced value of voltage. See Table 300-3-10.

300-3.5.3.2.3 Only the final high-potential test made on a winding shall be the ac high-potential test. The dc high-potential test shall be used on new or reconditioned windings as the initial test after winding or cleaning and prior to any varnish treatment. See paragraph 300-5.3.2.6 for testing propulsion equipment. However, if a high-potential test breaks down insulation or insulation is otherwise damaged after a high-potential test has been made, a second test shall be completed after repairs have been made.

300-3.5.3.2.4 All leads to the circuit being tested should be connected to one terminal of the source of test voltage. All leads to all other circuits and all metal parts should be connected to ground. No leads are to be left unconnected for high-potential tests as this may cause an extremely severe strain at some point of the winding.

300-3.5.3.2.5 For high-potential test of armature windings of ac machines, except propulsion generators and motors that have been completely rewound (not merely reconditioned such as cleaning, varnishing, baking or replacing other mechanical or electrical parts), test voltages should be applied to the interconnected phase windings by connecting the external leads of all these phases to one terminal of the source of test potential, all other windings and metal parts being grounded.

300-3.5.3.2.6 Alternating current propulsion generators and motors that are completely rewound (as distinguished from merely reconditioned) should be varnished and cured before the connection between phases is closed. The insulation between phases should then be tested by making a high-potential test of each phase with the other phases grounded. Both terminals of the phase being tested should be connected to the source of test potential. After the phases are interconnected and the connection is insulated, another high-potential test should be made on the interconnected phase windings, using the same voltage as before.

300-3.5.3.2.7 The high-potential test voltage should be 60-Hz alternating potential. (For dc high-potential tests see paragraph 300-3.5.2). When an ac high-potential test is made, it is important that the test transformer be of ample size and capacity. If too small a transformer is used, there may be positive regulation (with a capacitance load) which produces a rise in the transformer output resulting in a higher test voltage than intended. The 60 Hz source of potential should have a capacity of at least 1 kilovoltamperes. When making a test, the voltage should be increased to the maximum test voltage as rapidly as possible without overshooting the maximum value and should be maintained for 1 minute. The voltage should then be reduced at a rate that will bring it to one-quarter value or less in not more than 15 seconds. Perform a 500 volt megger test after the high-potential test.

300-3.5.3.2.8 The effective (root-mean square) voltage for a high-potential test on generators and motors should be as given in Table 300-3-10. It is to be noted that Table 300-3-10 gives different values of test voltage for the following two cases:

a. Circuits which have been reconditioned but have not been restored to a condition which should be as good as new.
b. Circuits which have been rewound or replaced and restored to a condition which should be as good as new.
c. It should be noted that voltmeter scales of ac high potential test equipment are generally not marked to enable setting voltages to exact values specified in Table 300-3-10. For example, when using a scale 500 volts per division, the calculated ac high potential voltage for a 440V motor would be rounded to 1300V and set approximately three fifths of the way between the 1000V and the 1500V scales.

300-3.5.3.2.9 When some of the circuits in a machine have been restored to a condition which should be as good as new, and others have not, it is desirable that the circuits be given separate high-potential tests, each at the appropriate test voltage as given in Table 300-3-10. If it is not possible to make separate high-potential tests on the circuits that have and have not been restored to a condition as good as new, both should be tested at the voltage for the circuits which have not been restored to a condition as good as new.

300-3.5.3.2.10 The voltages for high-potential tests on propulsion-control equipment are given in **NSTM Chapter 235, Electric Propulsion Installations.** Control equipment other than propulsion-control equipment need not be given a high-potential test unless coils are rewound or replaced. When all coils are rewound or replaced, the complete control equipment should be given a high-potential test at 2E + 1,000 volts for equipment with a rated voltage (E) of 600 volts or less; at 2.25E + 2,000 volts for equipment with a rated voltage over 600 volts; and at 700 volts for engine starting motor controllers. When only a part of the coils are rewound or replaced, the rewound or replacement coils should be given a high-potential test at the foregoing voltage after the coils are installed in the control equipment but before they are connected to other elements.

300-3.5.4 VOLTAGE SURGE COMPARISON TESTS. Insulation between turns, layers, or phases is difficult to test except with special equipment and techniques; however, it is as important as the testing of ground insulation.

300-3.5.4.1 General. The surge comparison tester uses the principle of impedance balance to simultaneously test turn-to-turn, coil-to-coil, phase-to-phase and coil-to-ground insulation; in addition, qualitative evaluations are made of a winding's likelihood of satisfactorily passing resistance, impedance, turn balance, and high-potential tests.

300-3.5.4.2 Surge Tester. The surge tester is an electronic device designed specifically to stress the whole winding's insulation system by applying a series of pulses between turns of a coil, between coils, between phases of two windings or two legs of a winding, and from the windings to ground to detect short circuited turns, coils or phases in the windings under test. The insulation system is stressed by application of a series of pulses having a very quick rise time of approximately one microsecond. As the pulse travels along the windings or legs of a winding, it produces a voltage distribution across them. The resulting voltage decay pattern of each of the windings is then displayed on the cathode ray screen. If the windings have no faults and are balanced, the two patterns will be identical and only a single trace will appear on the screen. However, if one of the windings has an insulation defect or winding fault, its oscilloscope pattern will not be the same as the trace for the good winding. Therefore, a double trace will be shown indicating the presence of a fault (see Figure 300-3-15)

300-3.5.4.2.1 When used at low current levels, the surge test will not cause damage to the windings under test because the duration of the surge is very short; therefore, the average power dissipated is very low. However, the voltage can be increased enough so that insulation breakdown and arcing can be observed. When used in conjunction with the dc high-potential test and insulation resistance test to determine the insulation condition, the surge test can be used on a go or no-go basis and is a very useful diagnostic device and quality control shop test when reconditioning or rewinding wound components.

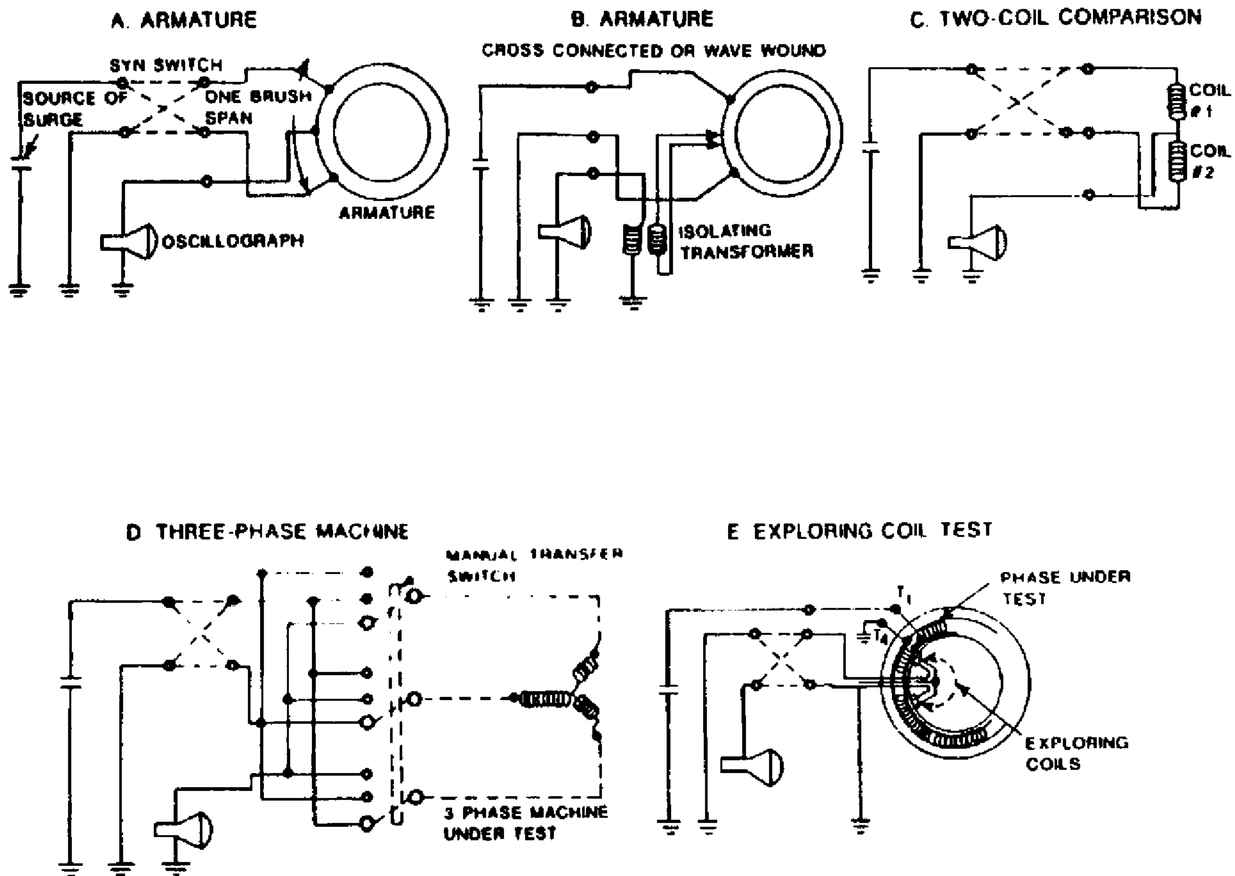


Figure 300-3-14 Typical Surge Comparison Test Connections

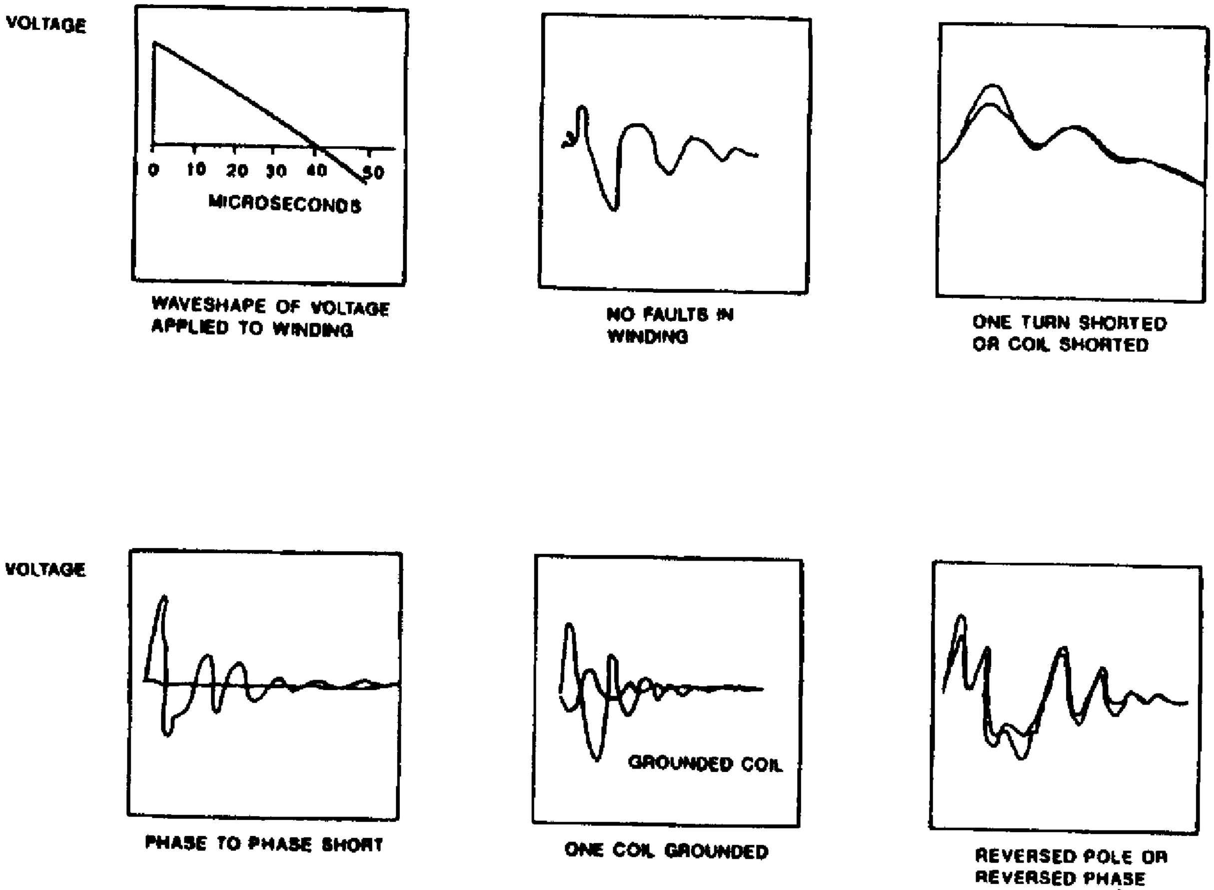


Figure 300-3-15 Typical Surge Comparison Test Waveshapes

300-3.5.4.2.2 Rewound or reconditioned components should be given a surge comparison test before varnishing so that winding faults such as shorted turns or coils, reversed coil groups or phases, and incorrect number of turns in a coil can be corrected before the windings are treated with varnish.

300-3.5.4.2.3 All naval shore repair facilities, tenders, and repair ships are authorized to use the surge comparison tester in the maintenance and overhaul of electrical rotating equipment. The technical manual supplied with each surge tester should be carefully studied before operating the instrument. Safety precautions, calibration procedures, and operating instructions should be followed in detail for safe, proper operation.

300-3.5.4.2.4 The test equipment shall conform to the following:

a. The tester should be able to vary voltage smoothly from zero up to maximum required.

b. A maximum voltage of not less than 5,000 volts is recommended for at least one tester at each activity. Shore activities repairing motors and generators rated higher than 440 volts should have a tester with a maximum voltage of not less than 10,000 volts.

c. Each activity should have at least one tester that is small enough to be carried through ship hatches.

300-3.5.4.2.5 Surge testers are available from (among others) the following:

a. The following testers contain mercury vapor tubes and should not be used on nuclear submarines or in mercury exclusion areas:

General Electric Company West Lynn, MA	Cat. No. 112L829G4 10KV
Westinghouse Electric Corporation Lima, OH 45802	Model P/N 976J552-1 10KV
Baker Instrument Company Denver, CO 80552	Model WT 10000 10KV

b. The following testers can be carried through a 25-inch hatch, do not contain mercury vapor tube, and are suitable for use on nuclear submarines and in mercury exclusion areas:

Baker Instrument Company Denver, CO 80522	Model ST 106H 6KV Model ST 112H 12KV
P. J. Electronics Monroeville, PA 15146	Model 8706 6 KV Model 6910C 10 KV

300-3.5.4.3 Armature Testing. The conventional test is to apply the surge across one brush span and observe the voltage at the middle of the span as the armature is rotated. A typical test connection is shown in Figure 300-3-14A. For cross-connected or wave-wound armatures, where the comparison method may be inadequate, the bar-to-bar voltage measuring circuit shown in Figure 300-3-14B may be used. Short-circuited or grounded coils may be located by this method.

300-3.5.4.4 Two-Coil Comparisons. Coils of various sizes can be tested in the manner shown in Figure 300-3-14C. Dc field coils or delta-connected ac stator windings can be tested by this method by breaking the connections or testing before all connections are made and comparing one coil or phase of the winding to the other coil or phase.

300-3.5.4.5 Three-Phase Machines. Three phase motors and generators of various sizes can be quickly tested with the technique shown in Figure 300-3-14D. Detection of one turn shorts or grounded coils is possible using this method on windings of small and medium sized units with only a few parallel paths. Many large motors and generators use windings in parallel. These connections are typically 2-Delta or 2-Wye, 4-Delta, or 4-Wye. These types of connections present a unique set of problems for testing by surge comparison or resistance testing. Because of the parallel paths, one impedance difference in one conductor will be averaged among the total conductors. For example, a phase winding with four parallel paths may have a short in one of the windings, producing a 5 percent impedance drop. However, when tested in parallel with the other three windings, the total phase impedance would vary by about 1 percent. A 1 percent imbalance is the least that can be detected by the surge test. So under these conditions, a fault may not be detected. For best results, each winding should be tested individually. That is, do not test the fully connected phase winding. Test each of the parallel windings separately. Use the same voltage that will be applied to the fully connected winding.

300-3.5.4.6 Test Voltage. The test voltage to be applied to the rewound component shall be 1.4 times the normal ac high-potential voltage given in Table 300-3-10, except for ac and dc motors rewound using a sealed insulation system which shall be tested at 5,000 volts. Reconditioned, or cleaned and revarnished, windings shall be tested at 2/3 of the test value specified for rewound components.

300-3.5.4.7 Waveshape Interpretation. While it may be difficult to positively identify the type of winding fault based on the waveshape displayed on the oscilloscope, a double trace indicates that a fault exists in the winding and further investigation should be made to correct the fault. Experienced operators are often able to diagnose the fault based on the waveshape. Typical examples of waveshapes are given in Figure 300-3-15. Double lines at the top of the trace and at the horizontal centerline for formed wound stators are typical and do not indicate failures.

300-3.5.4.8 Validity Test. If there is a question as to whether the unit in test has a failure or if the problem is in the surge test unit, the following test can be run:

1. With surge tester leads 1-2-3 connected to wound stator/core leads 1-2-3, check and note the switch position which shows the improper patterns.
2. Connect surge tester leads 1-2-3 to wound stator/core leads 2-3-1. Check and note the switch position which shows the improper patterns.
3. Connect surge tester leads 1-2-3 to wound stator/core leads 3-1-2. Check and note the switch position which shows the improper patterns.

300-3.5.4.8.1 If the improper pattern has shifted switch positions with the leads then the imbalance is in the wound stator/core.

1-2-3 to 1-2-3 bad pattern in position 2

1-2-3 to 2-3-1 bad pattern in position 1

1-2-3 to 3-1-2 bad pattern in position 3

300-3.5.4.8.2 If the improper pattern has not shifted switch positions with the leads then the imbalance is in the surge test unit.

1-2-3 to 1-2-3 bad pattern in position 2

1-2-3 to 2-3-1 bad pattern in position 2

1-2-3 to 3-1-2 bad pattern in position 2

300-3.5.4.8.3 With leads connected normally (tester leads 1-2-3 on stator leads 1-2-3), switch surge tester to each test position in turn and note the two pair with the similar pattern (usually bad). The phase common on each test position is the phase with the fault. For example, if 1-3 and 2-3 have similar (bad) patterns the failure is in phase 3.

300-3.5.4.8.4 The tester applies a voltage to two phases for each test position. The image on the screen is the comparison of the waveshapes of the voltage in the two phases. If both are the same the traces lie on top of each other and form one line. If the two phases are not the same the traces are not similar and double lines appear, particularly in the vertical legs of the traces.

300-3.5.5 DC FIELD POLES AND COILS. The surge comparison test can be used to compare field poles, solenoid and similar coils, however coil inductance tends to result in such brief oscillations that a clear fault indication is difficult to observe. A dc voltage drop test in accordance with paragraph 300-4.7.12.1.1 is a more preferable method.

SECTION 4.

MAINTENANCE OF ELECTRICAL EQUIPMENT

300-4.1 GENERAL

NOTE

Shipboard planned maintenance shall be in accordance with Maintenance Requirements Cards (MRC) when the Planned Maintenance System (PMS) is installed.

300-4.1.1 SAFETY PRECAUTIONS. Before attempting any maintenance or repair work on electrical equipment, be sure the equipment is disconnected from the power supply and that it cannot be inadvertently energized by someone who does not know of the work being performed. If there is any doubt as to whether the supply circuits have been deenergized, they should be checked with a voltmeter or voltage tester.

300-4.1.1.1 Safety Checks on Accessories. Motors and generators are frequently equipped with various accessories having separate sources of power. Internal illuminating fixtures, internal heaters, and external powered temperature detectors and alarm contacts are examples of accessories whose terminals must be deenergized when working on motors and generators. Check to insure that all such separate circuits are deenergized prior to attempting any maintenance or repair work on the equipment. Check the wiring diagram to determine if there are any capacitors that should be discharged by connecting their terminals to each other and to ground by use of a wire on an insulated handle. An exception to the rule for deenergizing the equipment may be made when it is necessary to observe operation. In this case, observe safety precautions necessary to prevent shock or arcs which might start fires or ignite explosive vapors. Refer to Section 2 for general electrical safety precautions.

300-4.1.1.2 Safety Checks on Controllers. If an electrical powered auxiliary must be operated manually and at the same time the associated controller must be energized to facilitate the location and correction of faults, then the following procedure should be observed:

1. De-energize the controller at the supply panel.
2. Disconnect the motor leads from the line contactor in the controller and insulate (tape) the terminal lugs.
3. Check circuits to component equipment (such as brakes) to make sure that malfunctioning of the component (such as release of brake) cannot occur when the control circuit is energized. Disconnect leads if necessary.
4. Energize the controller.

5. When the fault has been located and corrected, deenergize the controller and reconnect leads.
6. Make sure that all master switches are in the OFF position and that the equipment is properly set for power operation before again energizing the controller.

300-4.1.2 PURPOSE OF MAINTENANCE. The essential purpose of maintenance is to ensure that equipment is in all respects ready for service at all times. The following are some primary considerations for satisfactory operation of electrical equipment:

a. All circuits are connected correctly
b. Electrical contacts are clean, tight, and of low resistance
c. Moving parts function freely and in the way they are designed to operate
d. Electrical insulation is in good condition; clean, dry, and of high resistance

300-4.2 PREVENTIVE MAINTENANCE

300-4.2.1 GENERAL. The following measures are intended to reduce future repairs to a minimum. They should be considered as preventive maintenance and, as such, have been kept at a minimum so that their cost will not be out of proportion to the cost of future repairs. Due to varying conditions which may be found on different ships, judgment should be used as to where preventive maintenance should exceed the amount specified herein or, where conditions warrant, tests may be made at less frequent intervals.

300-4.2.2 PERIODIC CLEANING AND INSPECTION. A regular schedule of cleaning and inspection will go far toward ensuring trouble-free operation and detection of incipient faults before they develop into a major source of difficulty. Where definite times for cleaning and inspection are not specified in the instructions given in this chapter for different types of equipment, each ship should set up a practical schedule for periodic cleaning and inspection at intervals sufficiently short to keep the equipment in good shape. In setting up such a schedule the following should be considered:

a. New equipment should be carefully watched until extended operation has demonstrated that it is performing satisfactorily.
b. Old equipment requires more frequent cleaning and inspection than similar equipment which has seen less service.
c. Time spent in cleaning, inspecting, and correcting defects before they grow serious means time saved in overhauls and repairs.
d. See paragraph 300-4.5.7.10 if cleaning in the ship fails to restore a machine’s insulation resistance.

300-4.2.3 EXPLOSION-PROOF ENCLOSURES. The gaps between the joint surfaces of explosionproof , group D enclosures for shipboard electric equipment should be checked each time fits are disturbed and at each overhaul, to ensure that they do not exceed safe limits. These enclosures conform to MIL-E-2036, which includes portions of the National Fire Protection Association’s (NFPA) National Electric code (NEC) - NFPA - 70, and will contain any spark or ignition within the enclosure and not permit ignition in the surrounding external atmosphere as a result of normal operation or failure of electrical circuits within the enclosure. The enclosures are intended for use in explosive atmospheres normally found on board Naval ships, most of which are listed in group D of the NEC, and among others include: gasoline, hexane, naptha, benzine, butane, alcohol, benzol, lacquer solvent vapors, or natural gas. Group D enclosures are not to be used in explosive atmospheres containing acetylene, hydrogen, manufactured gases, ethyl ether, or dust.

300-4.2.3.1 Gap Clearances. Gap clearances of group-D enclosures, which may be checked with thickness gauges (such as NSN 5210-00- 242-3926, 5210-00-274-2857, and 5210-00- 221-1986), should not exceed:

a. Plane joints - 0.010 inch
b. Stepped joint, cylindrical surfaces - 0.004 inch radial (0.008 inch diametral) where the plane fit is less than 1/4-inch wide; 0.008 inch radial (0.016 inch diametral) where the plane fit is 1/4-inch or more wide
c. Shafts of motors - 0.016 inch radial (0.032 inch diametral) for shafts centered by ball or roller bearings; 0.008 inch radial (0.016 inch diametral) for shafts not so centered. These dimensions are somewhat greater than those under a and b because the bearing structure is usually stronger and clearance must be adequate to permit shaft rotation.

300-4.2.3.1.1 Gaps between joint surfaces of explosion-proof enclosures designed for acetylene, hydrogen, manufactured gases, ethyl ether, or dust atmospheres should be measured and compared to the tolerances specified on equipment drawings. If the indicated clearances cannot be met, the equipment should be replaced with equipment which does meet these requirements. In no case should these gaps be gasketed or painted since this would destroy the basic function of the gap.

300-4.2.3.1.2 In addition to checking the gap clearances, the effectiveness of the stuffing tube leading into the enclosure should also be checked. Lead conduits and stuffing tubes that have deteriorated or been damaged should be replaced with the same type and construction as originally installed.

300-4.2.3.2 General Maintenance. Relative to the general maintenance of explosion-proof enclosures, holes shall not be drilled through explosion-proof enclosures; enclosure parts shall not be machined in such a manner as to decrease the gap length (as contrasted to thickness) and hence flame path; bolts shall not be omitted nor permitted to become loose; and bolts of diameter smaller than the original shall not be used. Where parts are specifically selected for nonsparking characteristics do not use materials with sparking characteristics such as steel for replacement parts.

300-4.2.3.3 Other Limited Applications. Although time-proven explosion-proof enclosures are still a basic choice where hazardous areas are involved, there are other approaches which have found limited application on board ship. Two of these approaches are:

a. Sealing. These designs are usually identifiable by the seal which is in contrast with the heavy-duty, unsealed flanges of explosion-proof enclosures. Two methods of sealing are:
    1 Completely filling the voids of the equipment with fluid. This is the approach which has been taken in the case of submersible pumps and similar equipment.
    2 Hermetic sealing. These enclosures are rigid, of non-porous material such as metal, glass, or ceramics, and sealed by a fusion process such as soldering or welding.
b. Intrinsic safety. Intrinsically safe equipment and circuits are defined as being incapable of releasing sufficient electrical energy under normal or abnormal conditions to cause ignition of a specific hazardous atmospheric mixture. Items in this category have very low power ratings and are appropriately labeled. They usually have either a self-contained power supply (such as a dry-cell battery) or an arrangement which separates them

physically and electrically from the main power source. The maintenance requirements for explosion-proof equipment obviously do not apply to either of the foregoing approaches.

300-4.2.4 RECORDS AND REPORTS. Maintenance records add greatly to the value of inspection. Records which reveal progressive deterioration and repetition of repair jobs indicate the necessity for a deeper investigation into the cause of trouble. Reports based upon such records form the basis for changes in design, application, or method of operation to eliminate future faults and difficulties, increase the ease and dependability of operation, and insure the safety of personnel and long life of equipment. The Ship's 3-M System is a management tool developed to provide efficient, uniform methods of conducting, recording and reporting preventive and corrective maintenance of equipment. Preventive maintenance includes action taken to prevent equipment from failing and corrective maintenance includes actions taken to fix equipment that has failed or is not working as well as it should.

300-4.2.4.1 Ship's 3-M System. The Ship's 3-M System consists of two systems:

a. Planned Maintenance System (PMS) Concerned with preventive maintenance

b. Maintenance Data System (MDS) Concerned with the collection of maintenance and configuration data.

300-4.2.4.2 Maintenance Data System (MDS). The MDS is a system for the collection of data concerning corrective maintenance and configuration changes. The data collected includes: manhours expended by rate, parts usage, and a brief description of the problem and the maintenance required and/or performed. The data collected by MDS is used for several purposes:

a. Current Ships Maintenance Project (CSMP)

b. Automated printout of PREINSURV deficiencies

c. Automated printout of work requests

d. Configuration control

e. Automated reports

f. Machinery history.

300-4.2.4.3 The automated printouts available to the user through the 3-M system via the MDS are detailed in the **Ship's 3-M Users Manual** (NAVSEA SL790-AB-URM-010/3-M).

300-4.2.5 PAINTING. Special precautions are necessary when removing paint or repainting electrical equipment. In general, the removal of paint from electrical equipment should be avoided. The use of scraping or chipping tools on such equipment is liable to injure the insulation or damage relatively delicate parts. Furthermore, paint dust is composed of abrasive and semiconducting materials which impair effectiveness of the insulation.

300-4.2.5.1 Electrical Equipment Protection. All electrical equipment, such as generators, switchboards, motors, and controllers should be covered to prevent entrance of the paint dust when paint is being scraped in the vicinity. After completion of paint removal, the equipment should be thoroughly cleaned, preferably with a vacuum cleaner if available.

300-4.2.5.2 Repainting. Repainting of electrical equipment should be done only when necessary to prevent incipient corrosion due to lack of paint. Painting should be confined to areas affected. General repainting of electrical equipment or enclosures for electrical equipment for the sole purpose of improving appearance is not desirable. Paint should never be applied to any insulating surfaces in electrical equipment. See **NSTM Chapter 631, Volume 2, Preservation of Ships in Service (Surface Preparation and Painting)** , for instructions on painting.

300-4.2.5.3 Other Painting Precautions. Do not paint over identification plates, or rubber sound isolation mounts.

300-4.2.6 REPAIR PARTS. On board repair parts should be securely stowed in a clean, dry location and should be protected so far as possible, from high humidity, low temperature, and sudden changes of temperature. Repair parts not enclosed in moisture-tight containers should be safeguarded against sweating and freezing. Finished surfaces should be slushed or painted to prevent rusting. Periodic turning of spare armatures and rotors is not required.

300-4.2.6.1 Repair Parts Record. Complete and accurate records of onboard repair parts should be maintained. Repair parts should be replaced as soon as practical when used.

300-4.2.7 REORDERING AND REFERENCING INSTRUCTIONS. When it is necessary to reorder or to refer to any equipment or part, it is imperative that all available data be listed. This includes all identification plate data (such as manufacturer, equipment type, designation, equipment catalog, drawing, or style number, manufacturer shipping order or serial number), manufacturer and Navy drawing numbers, the data stamped, engraved, or otherwise marked on equipment parts, or listed in the list of repair parts, on applicable drawings, or in the ships allowance list. Incomplete data are the prime reason for delays in delivery of parts or receipt of incorrect replacement parts aboard ships.

300-4.3 PROTECTION FROM MECHANICAL SHOCK

300-4.3.1 EFFECT OF MECHANICAL SHOCK ON PREWAR EQUIPMENT. Experience gained in World War II showed that high-impact mechanical shock caused by noncontact underwater explosions of near-miss aerial bombs, torpedoes, and mines could result in extensive damage to, or derangement of, electrical equipment. The effects of high impact shock upon electrical equipment can be classified into two major groups:

a. Mechanical Breakage or Deformation. Inadequately designed equipment may fail mechanically in one or more of the following ways:
   1 Rupture of the framework or internal components
   2 Breakage of the mountings allowing equipment to come adrift
   3 Plastic deformation of components or hold-down bolts of sufficient magnitude to permit misalignment of units causing equipment to become inoperable

b. Improper Operation Without Mechanical Damage. Equipment sufficiently rugged to withstand high impact shock without mechanical damage may fail to operate properly under shock conditions. Typical cases of improper operation are:
   1 Circuit breakers opening when closed or closing when open
   2 Motor controller contactors opening when closed; or closing when open, causing idle motors to start unexpectedly with possible danger of injury to personnel or damage to equipment, and with the possibility of large starting currents which may cause tripping of circuit breakers

3 Tripping or closing of relays, causing unusual and sometimes dangerous operation of electrical equipment.

300-4.3.2 SHOCK RESISTANCE IMPROVEMENT. Much progress has been made in the design and production of electrical equipment that is resistant to high impact shock. The preferred method is to produce equipment which is inherently shock-proof and which requires no special mountings. This has been successfully accomplished for a wide variety of electrical equipment, including many devices which were originally believed to be inherently incapable of withstanding high-impact shock.

300-4.3.2.1 Shock Mounts. In cases where it has not been possible to provide equipment with inherent shock resistance, shock mounts may be designed which absorb the shock sufficiently to protect the equipment mounted on them. In some instances, shock mounts have been provided for an entire ships service switchboard in surface ships, and for electric propulsion control equipment in submarines and surface ships. Shock mounts must be very carefully designed because a poorly designed shock mount may be much worse than a rigid mount.

300-4.3.2.2 Shock Mount Approvals. In all cases where operating personnel consider that shock mounts are required to improve the reliability of certain equipment with which they are familiar, the problem should be referred to NAVSEA for decision and action.

300-4.3.3 AVOIDING DERANGEMENT FROM SHOCK. The major problem of protecting equipment from derangement by mechanical shock is taken care of by provision of equipment which is inherently high impact shock resistant, or by provision of shock mounts for equipment which has not been produced with inherent high impact shock resistance. There are, however, certain things which must be done by operating personnel. These are:

a. Keep all bolts and mechanical fastenings tight. Equipment in which bolts and fastenings are tight will successfully withstand shock of an intensity that will wreck equipment in which bolts or fastenings are loose.

b. Never install a rigid connection between the foundation and the framework of equipment which is supported by the resilient members of a shock mount. Such a connection destroys the effectiveness of the mount and may result in serious damage to the equipment mounted on it.

c. Do not mount additional components on shock-mounted equipment, and do not stack different items of shock-mounted equipment on top of one another. The added weight may make the whole unit incapable of withstanding shock.

d. Do not make changes or alterations which will decrease the clearance provided when shock-mounted equipment is installed in order to allow for its movement on the shock mount. On all mounts, including very stiff cup-type rubber mounts, a relatively small vertical movement at the mount may result in lateral movements of an inch or more at the top or extremity of the equipment.

e. Shock mounts may deteriorate in the course of time, particularly shock mounts having rubber parts. Shock mounts should be inspected at intervals of not longer than 6 months and mounts showing evidence of deterioration should be replaced. Deterioration is shown if there is a significant decrease in the separation between the framework of shock-mounted equipment and the foundation to which the shock mounts are secured. The separation should be measured and recorded when the equipment is installed and when the shock mount is inspected so that any decrease in separation can be detected.

f. In as much as most shock mounts electrically insulate the unit from the ships structure, suitable flexible braided ground straps should be provided between the unit and ground.

300-4.4 PROTECTION FROM MOISTURE

300-4.4.1 EFFECT OF MOISTURE. Water or excessive moisture on electrical insulation decreases the insulation resistance and may result in failure of electrical equipment. While the necessity of preventing electrical equipment from being subjected to the effects of water or moisture-laden air is obvious, the various ways in which damage may inadvertently occur on shipboard installations are sometimes overlooked. Prolonged exposure to high humidity may cause low insulation resistance on plate-type rheostats. Prior to plant start up, the rheostats should be dried out to remove surface moisture. (See paragraph 300-4.8.1.3 for grounding precautions.)

300-4.4.1.1 Two-pole, cylindrical-rotor ship service generator rotors shall be kept free of moisture. These units have nonmagnetic rotor retaining rings made of MnCr alloys. Several of these alloys are susceptible to stress corrosion cracking in the presence of moisture. Such cracking can result in failure.

300-4.4.2 WATER FROM VENTILATION DUCTS. Ventilation ducts and terminals near electrical equipment are a source of water and moisture that shall be considered. Experience has shown that, irrespective of the normal location of the weather terminals for a ventilation system, water may get into the ducts, either because of unusual sea and weather conditions, or as a result of damage to some portion of the ship, or because of firefighting or other emergency measures. Once in the ducts, the water will emerge from any parts of the duct which are not watertight, or from supply and exhaust terminals. Although due recognition is given in the design of a ship to the relation between ventilation openings and electrical equipment, subsequent changes necessitated by other considerations may overlook the importance of this matter. Serious derangements have occurred on naval ships as a result of seawater or spray being discharged from ventilation ducts upon electrical equipment. Such derangements have resulted in loss of electric power to vital functions, such as steering or guns, thereby endangering the military effectiveness of the ship and in some cases contributing to its complete loss.

300-4.4.2.1 Susceptible Equipment. The prevention of this kind of derangement requires elimination of the possibility that water or spray entering through or collecting on ventilation ducts and terminals will drip, splash, or be blown on electrical equipment. Particular attention is necessary to protect against water or moisture damage to the following electrical equipment:

a. Switchboards

b. Generators

c. Generator terminals

d. Propulsion motors of the open type

e. Transformer terminals

f. Open type control or distribution panels.

300-4.4.2.2 Corrective Measures. The following suggestions are given in order that ship's force may be aware of the changes and methods of correction which are within their own capacity of accomplishment when necessary. These are not intended to be all inclusive or restrictive. Other conditions and corrections will be apparent upon inspection of specific ships.

300-4.4.2.2.1 Where adjustable type ventilation terminals are installed so that they might inadvertently be turned to direct the air-flow toward electrical equipment, the terminals should be adjusted so that the airflow is directed away from the electrical equipment, and secured in that position by means of bolts or welding, with straps or brackets added if necessary.

300-4.4.2.2.2 Where terminals of the nonadjustable type are so located that moisture-laden air may blow against electrical equipment, baffles should be installed to prevent it. Such baffles may consist of sheet metal formed into semi-cylindrical shape and secured to the terminal in such a manner that the airflow is directed away from the electrical equipment.

300-4.4.2.2.3 Where terminals are so located that water might drip on electrical equipment even though the normal air flow is not directed toward it, the terminal should be relocated to avoid this possibility. The duct may be shortened or extensions added to obtain such relocation. Portions of the duct or its extensions, which are immediately above electrical equipment, should be watertight to prevent water dripping from joints in the duct.

300-4.4.2.3 Effect of Changes on Vent System. Revisions such as those suggested, involving change in direction of the airflow or changes in ventilation terminal locations, will not result in unsatisfactory temperature rises in the electrical equipment if the total amount of ventilating air entering and leaving the space is not appreciably changed, and reasonably wide separation between supply and exhaust terminals is provided.

300-4.4.3 WATER FROM PIPING. Derangement of electrical equipment may be caused by leakage from water piping, or by condensation on unlagged piping, dripping or splashing on the equipment. Every effort should be made to avoid this by proper location of piping and fittings or, where this is not practical, by use of drip shields. Where practical, water piping near electrical equipment should be in one continuous length to avoid possibility of derangement by water from leaking or broken joints.

300-4.4.4 HEATING TO KEEP IDLE EQUIPMENT DRY. When equipment is not in use, the space heaters installed in many generators and motors should be turned on to keep the insulation dry. This is particularly important in humid or cold climates. Motors provided with a sealed insulation system do not require heaters inasmuch as the motor can tolerate damp or wet conditions.

300-4.4.4.1 Electric Lamps As Heaters. If heaters are not provided in a machine, electric lamps can be placed within the machine as a temporary means until heaters can be installed. Covers of a nonflammable insulating type material may be used around open type machines to equalize temperature distribution and reduce the amount of heating required. A rough rule for estimating the heating capacity needed is to provide 100 watts for each ton of machine weight. All that is needed is enough heat to keep the air temperature within the machine about 5° F to 10° F above the ambient air temperature when the machine is secured.

300-4.4.4.2 Heating by Circulating Current. Another method of heating that can be used when space heaters are not provided is to circulate a small current through the shunt field circuit. To keep from overheating the winding, not more than 50 percent of the rated field current should be sent through the winding when the machine is secured, and less will usually be enough.

300-4.4.5 OTHER METHODS TO KEEP EQUIPMENT DRY. Implementation of the following is recommended:

a. Install drip covers or drip pans over electrical equipment likely to be damaged by water dripping from overhead.

b. Keep the seals in good condition where the ends of cable have been sealed against the entrance of water or moisture. Moisture reduces the insulation resistance of cable.

c. Coat absorbent surfaces of insulating material, such as the edges of insulating panels, with an air-drying insulating varnish.

d. Inspect watertight and waterproof joints in electrical equipment. Replace gaskets or employ sealing compounds as required.

e. Inspect to ensure that no water or oil is present in the bottom of machine enclosures. Drain as necessary. Make sure that plugs and piping (when installed) are left in a watertight condition.

f. Do not allow enough water to accumulate in the bilges to flood or splash on electrical equipment or cables. Pay particular attention to cables installed in wireways below floor plate levels, as these are the ones most exposed to the water in the bilges.

g. Inlet air for motors and generators, which take ventilating air from the machinery spaces, should be drawn from above the floor plate level to keep from drawing water spray into the machines. This would otherwise deposit on the windings, and might also cause the formation of verdigris on the commutators.

h. Use type HF (Heat and Flame Resistant) plastic sealer, conforming to MIL-I-3064, **Insulation Electrical, Plastic-Sealer** , around cables at terminal tubes and clamps to seal out moisture and vermin.

i. Inspect all shipboard electrical boxes equipped with air-test fittings to ascertain that the sealing screw and lead sealing gasket are in place and tight. If screw or gasket is missing, replace them. Use round-head, brass, machine screw, 6-32, 1/4-inch long. Use lead gasket 1/4-inch diameter, 1/16-inch thick, with a clearance hole just large enough for a 6-32 screw. If the replacement gaskets are not available, a few turns of twine saturated with white lead applied directly under the head of the screw, just before the screw is given the last two turns, will provide a satisfactory seal.

j. Add drip hoods over shore terminal boxes which have ill fitting cover gaskets, to exclude rain spray and drip. At joint of cable entering shore power plug connector, seal joint to prevent water from entering plug.

k. If electric motors are to remain idle for approximately 2 weeks or more and electric power is not continuously available to heat machines by methods in paragraphs 300-4.4.4 through 300-4.4.4.2, desiccant can be used to prevent condensation on motor windings. The following materials and procedures are recommended:

   1 Material. The desiccant should be composed of either silica gel or clay. Silica gel provides more absorbency than clay and is recommended for use with squirrel cage induction motors as well as all others that do not use carbon brushes. Clay is required with machines that use carbon brushes. Do not use silica gel with machines that use carbon brushes. Silica will cause carbon brushes to rapidly deteriorate. Desiccant is contained in Type II, non-dusting bags as identified in MIL-D-3464, **Desiccants, Activated, Bagged, Packaging Use and Static Dehumidification** . A bag is designated as an 8 unit (1 pound) or 16 unit (2 pound) size. The minimum quantity of issue is a 22 gallon drum containing 240 bags of 8 unit size (NSN 6850-00-935-9793). Specify the desiccant material with procurement.

NOTE

Bags of desiccant are never to be placed inside a motor enclosure.

   2 Procedure. Determine the number of units (not bags) of desiccant required by using the following formula from MIL-P-116, **Preservation, Methods of:** No. of Units = (CA) + (D_1 X_1) + (D_2 X_2) + (D_3 X_3) Where:

      A = Surface area (square feet) of barrier-wrap material enclosing motor and desiccant

C = 1.6 (Constant)

D_n = Pounds of each dunnage material (fiber, glass fiber, synthetic foam, rubber) within the motor barrier-wrap that is used to cover grease pipes, terminal boxes, and so on. (n=1, 2 and 3 and identifies the material type as defined below)

X_1 = 3.6 for fiber material

X_2 = 2 for glass fiber

X_3 = 0.5 for synthetic foams and rubber.

300-4.4.5.1 Attach to the motor frame a three spot humidity indicator card (NSN 6685-01-008-7563 or 6685-01-073-5408) in a location which can be easily seen. The card registers relative humidities of 30, 40, and 50 percent by a color change of spot. Wrap the motor, desiccant, and indicator card as securely as possible using transparent plastic sheet of at least 4 mils thickness (double wrap using NSN 9330-00-290-6149). Inspect the indicator card periodically, and replace the desiccant when the card registers 40 percent relative humidity.

300-4.5 CLEANING, DRYING, REPAIRING, AND VARNISHING INSULATION

300-4.5.1 CLEANING INSULATION - GENERAL. The importance of keeping all insulation clean cannot be overemphasized. Dust, dirt, and foreign matter (carbon, copper, and mica) tend to block ventilation ducts and to increase resistance to the dissipation of heat, resulting in local or general overheating. If particles are conducting or form a conducting paste through absorption of moisture or oil, the windings may eventually be short-circuited or grounded. Abrasive particles may puncture insulation. Iron dust is particularly harmful since the dust is agitated by magnetic pulsations. For these reasons, equipment should be cleaned both externally and internally, being particularly careful to keep all air ducts clean. In addition to wiping, there are acceptable methods of cleaning insulation; use of compressed air, use of suction, and use of a solvent. Wiping is effective in removing loose dust or foreign particles located in accessible parts of the machine only. The surfaces should be wiped with a clean dry rag that will not deposit lint. Cheesecloth is recommended for this purpose. When wiping, do not neglect such parts as the end winding, mica cone extensions at the commutator of dc machines, slip ring insulation, terminals and terminal insulation, and connecting leads. Place used solvent wiping rags in a container with tight fitting cover. These rags should be aired out only at topside locations.

WARNING

Improper use of high-pressure hose and horseplay has caused severe injuries to internal organs and eardrums. Never allow compressed air to contact or enter anyone’s body.

300-4.5.2 COMPRESSED AIR CLEANING. The use of compressed air is effective in removing dry loose dust and foreign particles particularly from such inaccessible locations as air vents in the armature punchings. Only compressed air that is clean and dry should be used. Air pressure up to 30 lb/in^2 may be used on motors or generators. Where air lines carry higher pressure than is suitable for blowing out a machine, a throttling valve should be used to reduce the pressure. Always allow any accumulation of water in the air pipe or hose to be thoroughly blown out before turning the air blast on the machine. Compressed air should be used with caution, particularly if abrasive particles are present, since these may be driven into the insulation and puncture it or be forced beneath insulating tapes. Compressed air should be used only after the machine has been opened up on both ends so as to allow a path of escape for the air and dust. It should be noted that the use of compressed air will prove of small benefit if the dust is not suitably removed from the machine. The most suitable method is to attach a suction blower to an opening in the opposite end from the air jet to remove the dirt-laden air.

300-4.5.3 SUCTION CLEANING. The use of suction is preferable to the use of compressed air for removing abrasive dust and particles since there is less possibility of damaging insulation. A flexible tube attached to the suction side of a portable blower will make a suitable vacuum cleaner which can be used for this purpose. The use of a suction blower attached to take suction adjacent to the commutator is particularly desirable to draw loose particles away from windings when stoning commutators or seating brushes. Grit, iron dust, and copper particles should be removed by suction methods whenever possible.

300-4.5.4 SOLVENT CLEANING. For the purpose of this document, the term solvent or solvent cleaning shall be construed to mean a cleaning process or material that is not water based, diluted with water or requires a water flush to remove film or residue. While solvent cleaning may be accomplished in a shorter time period than non-solvent cleaning, the results are comparable. The use of solvents for cleaning electrical equipment should be avoided insofar as practicable. However, when a solvent is necessary for cleaning, certain precautions must be followed and only approved solvents should be used. See paragraphs 300-5.2.3 through 300-5.2.3.4 for recommended organic solvents, precautions, and application information. Additionally, industrial solvent cleaning and revarnishing by activities specializing in electrical machinery cleaning may be effective in restoring equipment to service without the need for removal. For steam cleaning, see paragraph 300-5.2.2.1. See paragraphs 300-4.5.5 and 300-5.2.2 for guidance on use of water-based detergents.

300-4.5.5 HIGH-PRESSURE WATER SPRAY. The use of high-pressure spray using water and detergent is effective in cleaning windings of motors, generators and motor-generators. Cleaning by this method should be used only after other cleaning procedures such as hand wiping, use of vacuum and compressed air have been tried and have not been successful or where windings have been contaminated with hard to remove substances such as lube oil and carbon dust. High-pressure spray cleaning utilizes a high pressure airless sprayer BINK's Model 98-990 (SUPER BEE) or equivalent, approved for this use. Use BINK'S TITAN TIPS Model 341-049 or 341-041 and TIP GUARD Model 350-120. The sprayer is capable of delivering up to 0.5 gpm through an adjustable pressure range of 0 to 2500 PSI. Airless means that the water is atomized by high fluid pressure at the spray nozzle tip and requires no air supply. The output spray pressure will actually dissipate rapidly as distance from the nozzle tip is increased. The safety precautions in Section 2 must be followed when using this equipment. The warning in paragraph 300-4.5.1 for high-pressure air is fully applicable to high-pressure water spray. Do not use alternate type high-pressure sprayers without NAVSEA approval.

300-4.5.5.1 The cleaning solution shall consist of liquid non-ionic water soluble general purpose detergent, MIL-D-16791 (NSN 7930-01-055-6121, quantity 1 gal or NSN 7930-00-282-9700, quantity 55 gal) mixed in a proportion of 1 oz to 1 gal of fresh water heated to 130° to 150° F. If a different NAVSEA approved water-based detergent per paragraph 300-5.2.2 is substituted, the Material Data Safety Sheets or the manufacturer should be consulted to determine if any temperature restrictions are applicable. Safety precautions, operating instructions and sprayer clean-up procedures should be followed in detail for safe proper operation. The instructions supplied with each sprayer should be carefully studied before operating the equipment. See Figure 300-4-1, Figure 300-4-2 and Figure 300-4-3 for features of the sprayer.

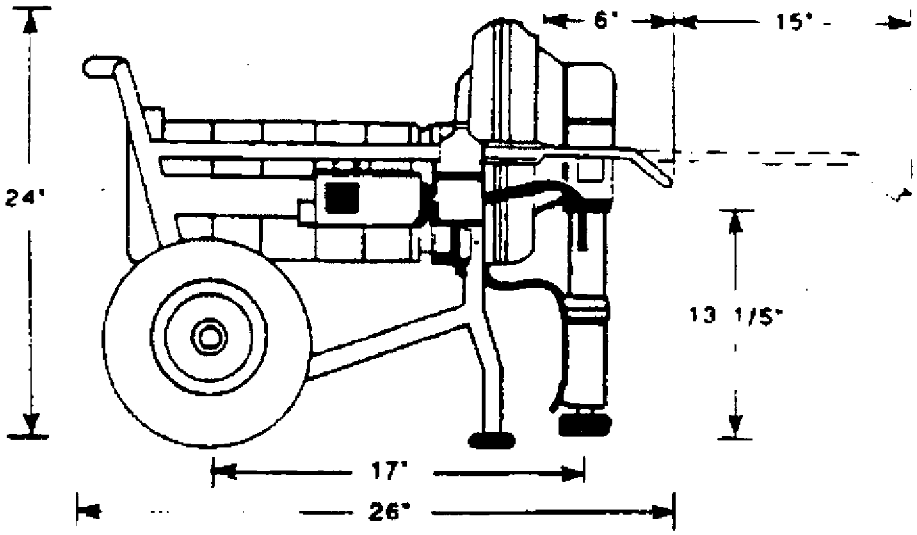
300-4.5.5.2 The following steps must be taken to ensure satisfactory operation of the equipment:

WARNING

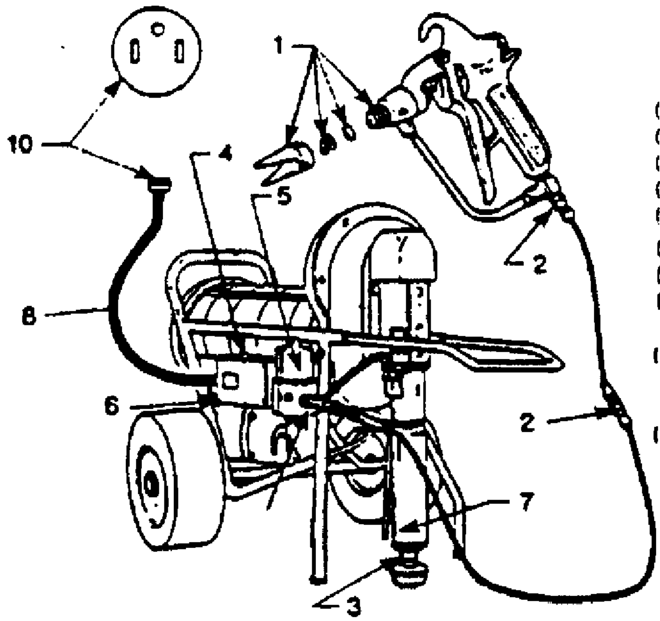
Do not use organic solvents in this high pressure sprayer due to the high toxicity of solvents when atomized and the high probability of an explosive mixture being formed. Where cleaning is done by a commercial activity using a solvent, the activity must certify that toxicity concerns are adequately addressed, and there is no possible danger of ignition of an explosive mixture.

NOTE

Use of this procedure in conjunction with in-place repairs of submarine motor generator armatures is only to be accomplished by personnel specifically trained in the use of this process and then only with the specific approval of Naval Sea Systems Command.



TYPICAL
DIMENSIONS



(1) THE SPRAY TIP   KEEP IT CLEAN
(2) ALL HOSE CONNECTIONS   KEEP TIGHT
(3) SIPHON KIT SCREEN   KEEP IT CLEAN
(4) ELECTRICAL SWITCH   ON
(5) FILTER SCREEN   KEEP IT CLEAN
(6) PRESSURE ADJUSTMENT   TURNED UP
(7) MATERIAL SUPPLY - KEEP LEVEL OVER PUMP
(8) PROPER EXTENSION CORD   USE MORE HOSE, NOT LONGER EXTENSION CORD
(9) REPLACE ANY DEFECTIVE PARTS IMMEDIATELY BEFORE CONTINUING OPERATION
(10) BE SURE THE ELECTRICAL PLUG IS CONNECTED TO THE ELECTRICAL OUTLET

Figure 300-4-1 High Pressure Water Spray Equipment

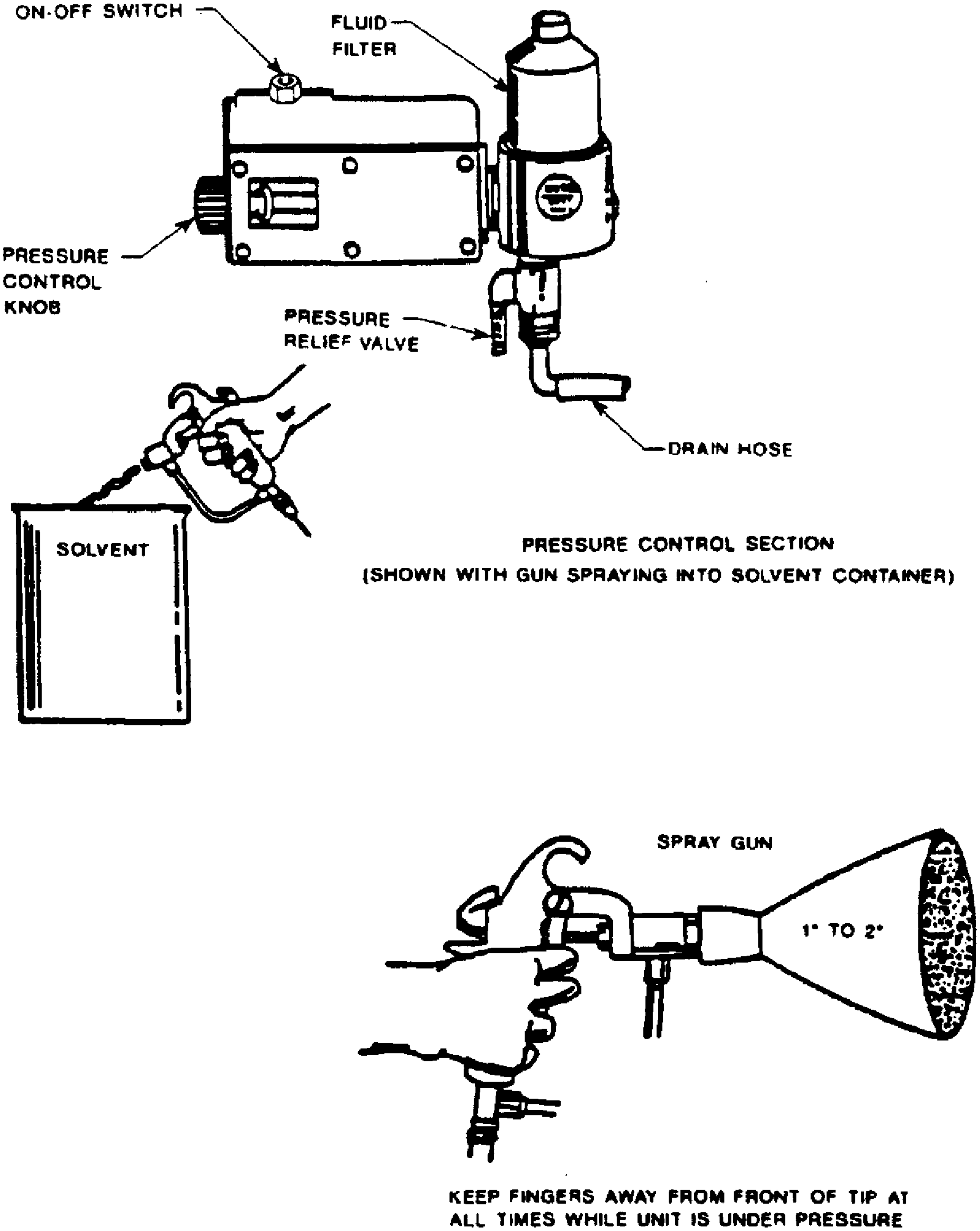
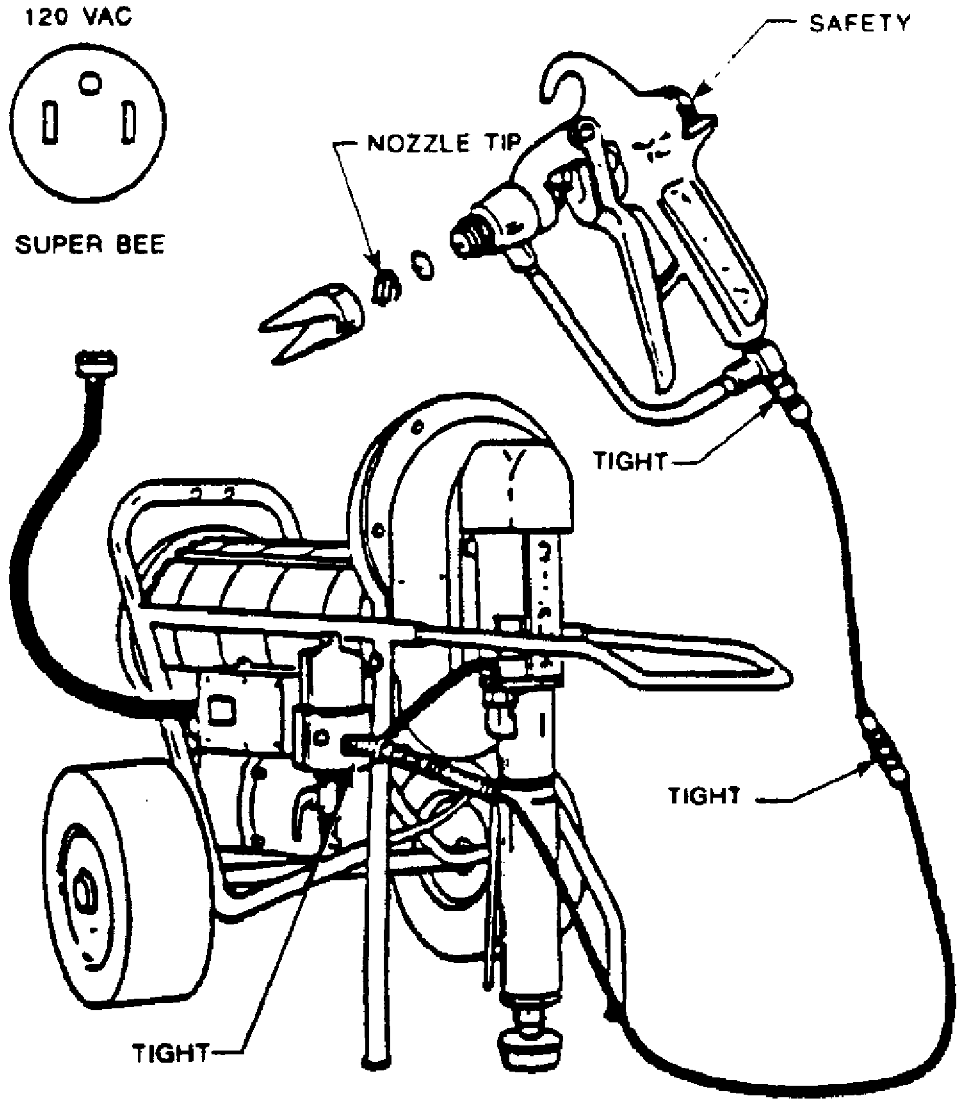


Figure 300-4-2 Pressure Control Section and Spray Gun



FLUID OUTPUT: 1/2 GPM
PRESSURE: ADJUSTABLE TO 2500 PSI.
ELECTRICAL REQUIREMENT: 120
VAC 60 HZ. 1 PHASE. 15 AMPS.
MOTOR: 3/4 HP EXPLOSION-PROOF
FLUID SECTION: CORROSION RESIS-
TANT MATERIAL
FLUID FILTER: MANIFOLD WITH RE-
PLACEABLE FILTER ELEMENT. FLUID
OUTLET. PRESSURE RELIEF VALVE.
WEIGHT: 39 POUNDS.

Figure 300-4-3 Airless Spray Gun - Complete Assembly

1. Before its first use, the water spray equipment must be cleaned and purged of any moisture or dirt in the system. Follow the manufacturer's instructions on initial flushing of the system.

2. Fill a container with hot detergent/water mix. Adjust pressure to approximately 2500 PSI. Turn unit on when cleaning solution begins to flow from pressure relief valve, close valve. Disengage gun safety and trigger gun into container until cleaning solution flows. Adjust spray pattern, normally to form fan as in Figure 300-4-2, by adjustment of ratchet on tip.

3. Spray windings until all carbon dust, oil, grease or foreign deposits are removed. Use clean lint-free cloths to check for cleaning effectiveness. At conclusion of wash, rinse windings using sprayer and hot fresh water. Wipe, and blow dry surface water. Dry windings per paragraphs 300-5.3.1 through 300-5.3.8.

4. After each use the sprayer equipment must be cleaned. All moisture must be removed. Follow manufacturer's instructions on cleaning the sprayer using the solvent (xylene) flush method.

CAUTION

Do not test transformer cores. The windings can attain dangerously high voltages. Similarly, an excessively high voltage can be created in multiple turn conductors that may have inadvertently been looped through the bore of a motor or generator. Do not test if such extraneous windings are present. Also, do not test ring wound armatures.

300-4.5.6 CORE TESTING. Core testing is mandatory for all motors requiring rewind when repairs are accomplished at any of the regional repair centers or at a depot level maintenance facility or contractor. For motors being repaired/rewound in a shipboard repair facility, core testing is optional. If a core tester is readily available to the shipboard repair facility, core testing is recommended when a motor has a history of repeated failures or when there is evidence of physical damage to the core based on visual inspection. Cores of rotating electrical machines are constructed from thin laminations insulated from each other to reduce core losses. The insulation prevents the alternating flux of the machine from inducing currents between laminations. This insulation may, however, be damaged during construction, service or maintenance, thus allowing excessive axial currents to flow, these in turn leading to troublesome local overheating or hot spots in the damaged area. Failure of interlaminar insulation during service may be caused by mechanical damage due to foreign objects or vibration. Whenever several laminations have become short-circuited due to these types of effects, the possibility exists that excessive local heating might arise, exaggerating the problem by affecting the interlaminar resistance in the environment of the original fault with danger of further overheating, leading eventually to coil insulation damage. These hot spots cause additional demand on the power source and reduce the efficiency of the affected machine. Core losses increase as a result of deterioration of or damage to the core lamination insulation (core plate) and result in energy losses and overheating of the machine. Core testing permits determination of the core conditions and is a valuable tool in avoiding rewinding of unacceptably high core stators or rotors. A core test should be performed prior to stripping and cleaning of the core. In this way, the time and effort to strip and clean the core can be saved if the test shows an unacceptable core. By the same token, a core test should also be performed after stripping and cleaning to ensure that the core was not damaged during the process. Where feasible, defective laminations can be replaced using laminations with C-5 core plate. The repaired core should then be dipped in solvent varnish and cured for rust prevention. The condition of the winding whether old, new, burned out, shorted or grounded has no effect on the core test results.

300-4.5.6.1 The condition of the core can be determined by the following methods:

1. Core testers are available that automatically determine the required flux density by using core measurements fed into the tester and then indicating the volts, amperes and watts settings for the test. A printout tape records the data and determines if the core is good, marginal or bad. A core tester such as a LEXSECO 1081 or equivalent shall be used.

2. If a core tester is not available, the following loop tests may be conducted to determine armature and stator core acceptability. Keep records of all data collected.

   a Initial ac stator core test made prior to stripping and cleaning.

      (1) Measure the stator core length (CL), core depth (CD), core bore diameter (CID) and slot depth (SD).

      (2) Effective stator core length (CL) is obtained as follows: CL = Measured core length x 0.80.

      (3) To determine the stator core depth (CD), measure from the bottom of the coil slot to the core's outer circumference.

      (4) Effective core cross section area = (CL) x (CD).

      (5) Estimated voltage per turn = 0.26 x core area.

      (6) The number of cable turns to be placed through the stator core = supply voltage divided by the estimated volts per turn.

      (7) Effective stator core diameter (ECD) = CID + (2SD) + CD.

      (8) Ampere turns (AT) = 45 x ECD

      (9) Current required = AT/Turns.

      (10) Select a cable size that has a current rating not less than that required to conduct the test as is calculated in step 9, above.

      (11) Wrap the required number of turns of insulated cable (calculated in step 6) around the stator axially (i.e., each cable loop or turn should be passed through the ID of the stator and then looped back over the OD of the stator).

      (12) Energize the cable to the supply voltage value and measure the current.

      (13) After one or two minutes with the cable energized, feel the surface of the core, identify one or two of the hottest areas, mark with chalk and designate them as hot spots. Determine also, and mark, an area which is closest to room temperature. Designate this as a cold spot. Deenergize the coil. See the note for optional temperature measurement technique in step 16.

      (14) Attach thermocouples to the areas designated as hot spots and cold spots and cover the thermocouples with plastic sealer (Duxseal). See the note for temperature measurement option in step 16.

      (15) Reenergize the coil at the supply voltage value and record the current and temperature of the hot and cold spots at ten minute intervals for a period of 1 hour unless severe overheating occurs. During testing, a nominal core temperature of 10° to 15° C above room ambient indicates sufficient flux to produce hot spots. Changing the number of cable turns may be required to maintain the core in the desired temperature range. If the temperature is less than desired, remove turns (two at a time) and observe the temperature.

      (16) If after one hour, the difference in temperature between the hot spots and cold spots exceeds 15° C (59° F) or the temperature of the hot spot exceeds 85° C (185° F) at any time during the test, the laminations must be replaced in the high temperature area. Replacement laminations shall have C-5 core plate in accordance with AISI surface insulation designations.

NOTE

An infrared scanner may be used to monitor the temperature as an option.

b Initial wound armature core test made prior to stripping and cleaning.

(1) Measure the armature core length (CL), core depth (CD), core bore diameter (CID) and slot depth (SD).

(2) Effective armature core length (CL) is obtained as follows:

CL = Measured core length x 0.80

(3) To determine the armature core depth (CD), measure from the bottom of the coil slot to the inner diameter of the laminated core.

(4) Effective core cross section is (CL) x (CD).

(5) Estimated voltage per turn = 0.26 x core area.

(6) The number of cable turns to be placed through the armature core = supply voltage divided by the estimated volts per turn.

(7) Effective armature core diameter (ECD) = CID + (2SD) + CD.

(8) Ampere turns (AT) = 45 x ECD.

(9) Current required = AT/Turns.

(10) Select a cable size that has a current rating not less than the current required to conduct the test as in step 9, above.

(11) Wrap the required number of turns of insulated cable (cable turns calculated in step 6) around the armature axially, i.e., each cable loop or turn should be passed through the spider of the armature and then looped back over the OD of the armature.

NOTE

In the event that the armature core does not have a spider or physically does not have adequate space to wrap the required turns, use a single series loop with the following guidelines:

(a) The single turn series loop is limited to the ac current source available within the rewind facility. In most cases this will be 1000 amperes.

(b) The single turn series loop consists of a shaft clamp at each end of the rotor shaft and the associated current carrying cable connected to a controlled current source to form a series loop.

(c) If space and current carrying capacity dictates, the series loop may be configured with two parallel shaft clamps and associated current carrying cables at each end of the rotor shaft.

(d) The controlled ac current source may be any source available within the rewind facility including an ac welding set.

(e) If the current requirements exceed 1000 amperes then the rotor core test should be performed by using a motor core tester, such as LEXSECO Model 1081; Adwell Industries Ltd EL-CID; or equal.

(f) A standard GROWLER test may also be used to help identify a damaged rotor core.

(12) Repeat steps 12 through 16 of the ac stator core test, using the same pass-fail criteria.

300-4.5.7 REPAIRING DEFECTIVE INSULATION.

CAUTION

The use of any silicone base materials, such as insulation, gaskets, cables, lubricants or sprays in non-ventilated machines containing brushes is prohibited. Silicone materials in any form shall not be used in submarine motor-generator sets because of excessive brush wear problems.

300-4.5.7.1 Rewinding Machines with Random Windings. All available information concerning the machine should be reviewed prior to starting the work. This includes reviewing available Material History Card (NAVSEA 527A), the Resistance Test Record Card (NAVSEA 531) (Table 300-3-4), the master drawings, technical manuals, and pamphlets. Carefully record the winding extension by measuring the length, thickness, inside and outside diameter, winding flare, and frame clearance. Use a pattern or template to retain the winding configuration. This information is critical for replacing windings with close clearances. Where feasible, assemble end bells to the frame to insure that the winding shape is correct. A 1/8-inch clearance between winding and frame should be maintained. Remove end bells prior to varnishing the winding.

300-4.5.7.2 Stripping Procedures. If armature or stator laminations are satisfactory, strip the windings and insulation. Record all data (size and type of magnet wire, number of turns per coil, coils per pole, pitch, number of poles, number of slots, connections, and similar data) and compare with the specifications given in the appropriate Technical Manual. Stripping procedures should be used that ensure that the interlaminar core plate is not damaged. The following practices should be followed when stripping wound components:

a. No open flame or torch shall be used on laminated iron surfaces.

b. If solvent stripping (other than vapor degreaser) is used, ensure by inspection that the solvent is not retained or trapped between laminations and that the solvent has not damaged the core plate.

c. A water blast stripping technique may be used where appropriate.

d. When a burn-out oven is used, the maximum surface temperature of the laminated iron surface should be measured on the iron by thermocouple and shall not exceed 370° C (698° F).

e. Very light abrasive blasting may be used to clean laminated surfaces. Organic materials or glass beads may be used. Sand or grit shall not be used. In all cases, laminated surfaces shall not be damaged by the abrasive used.

f. All varnish and insulating materials shall be removed from the slots. All varnish accumulation on the iron and other surfaces must be removed. Ensure all air passages, vents, holes, etc. are clean and free of old varnish or other material.

g. Repeat core test (paragraph 300-4.5.6.1). Repair or replace any defects noted.

h. The cleaned core should be preheated, and given a single dip and bake using a solvent type varnish and the procedure of Table 300-4-1.

300-4.5.7.3 Silicone Insulation Restriction. The rewinding of Class A, B, F, H or N motor with silicone insulation is no longer authorized or approved. The need for special tanks and dipping facilities is not cost effective when coupled with the erratic supply problem with the varnish. See caution in paragraph 300-4.5.7.

300-4.5.7.4 Electrical Tests. Prior to varnishing, after the winding has been completed it should be checked electrically for continuity and for shorted turns.

300-4.5.7.5 Varnishing. The armature or stator should be varnish-treated in accordance with paragraph 300-4.5.8 and the procedure shown in Table 300-4-1.

Table 300-4-1 VARNISHING PROCEDURE (SOLVENT VARNISH)

Procedure	Processing Rebuilt Armature Coils, Stator Coils and Field Coils
	Class A, B, F, H and N
Step 1 Prebaking	Put into oven at 150° C (302° F). Hold at temperature for 2-4 hours depending on size of equipment. Cool to approximately 60° C (140° F) by convection. If necessary, forced air cooling may be used provided the air is filtered with a 50 micron filter.
Step 2 Dipping	Immerse coils preheated to 60°C (140°F) in organic varnish (see Table 300-4-2 for varnish selection) until bubbling stops. Viscosity should be as indicated in the varnish manufacturers' instruction sheets or product literature. Dip wound rotating components with the commutator, slip ring or connection end up.
Step 3 Draining	Drain vertically and air-dry for 15-30 minutes. Periodically turn wound apparatus end for end during draining to prevent pocketing the varnish. For wound rotating components, drain with commutator, slip ring or connection end down; do not rotate.
Step 4 Cleaning	After draining but before baking, the metal surfaces of the armature, the bore of the stator and the pole faces of the field structure should be cleaned by wiping with a cloth moistened with solvent.
Step 5 Baking	Bake in a circulating type forced exhaust oven, with a minimum of six air changes per minute, at 150°C (302°F), for 2-3 hours. Baking time begins when the equipment is at the baking temperature. For class H and N varnishes, bake at the lowest temperature recommended by the varnish manufacturer.
Step 6 Cooling	Remove from oven and cool to approximately 60° C (140° F).
Step 7 Second treatment	Repeat steps 2, 3, 4, 5 and 6. The duration of the immersion in step 2 should be until the bubbling stops but not less than 2 minutes. The baking time in step 5 should be 6-8 hours. Dip wound rotating components with the commutator, slip ring or connection end down. Drain with the commutator, slip ring or connection end up; do not rotate.
Step 8 Third treatment	For wound rotating components, repeat step 7 except that dipping should be with the commutator, slip ring or connection end up. Drain with commutator, slip ring or connection end down; do not rotate.
NOTE: This procedure applies to solvent-type varnish (see Appendix A). For in-place varnishing using solventless varnishes, see Appendix E. For vacuum pressure impregnation, see Appendix B or Appendix C. For dipping in solventless varnish, see paragraph 300-4.5.8.2.	

300-4.5.7.6 Rewinding Squirrel-Cage Induction Motors with a Sealed Insulation System. Rewinding with sealed insulation system (SIS) shall only be done by those shore activities that have been certified by NAVSEA. Each certified activity shall use those materials specified in the NAVSEA certified SIS procedures in lieu of OEM specified materials.

a. A family of materials and procedure steps have been developed for ac and dc motors. Using solventless epoxy type varnishes and vacuum pressure impregnating (VPI) equipment, the sealed insulation system provides maximum moisture protection.

b. Encapsulated motors requiring rewind shall be rewound with a sealed insulation system. The encapsulation process is obsolete and has been replaced by the sealed insulation system.

c. Wherever possible, ac and dc service A motors (refer to motor drawing for service designation) with Class A, B or F non-sealed insulation whose insulation resistance cannot be restored after reconditioning (see Table 300-3-6) shall be rewound by a NAVSEA certified facility using a sealed insulation system.

d. Since sealed insulation is thermally rated as Class F, the following procedure shall be followed when Class H or N non-sealed insulation motors are to be rewound:

1 Service A, Class H and N insulated motors shall be rewound with a Class F sealed insulation system if the total temperature of the winding when operating at rated horsepower is no greater than 155° C. The total temperature is the sum of the motor's rise by resistance and the maximum ambient temperature. Both quantities are shown on the motor drawing. The rise by resistance is located in the temperature rise test data section of the drawing. The maximum ambient temperature is located in the drawing classification block and on the motor nameplate.

2 If the total temperature, as determined above, is greater than 155° C, Class H or N as applicable shall be used.

3 If the motor drawing is not available and there is no available application information to verify acceptability of a Class F insulation system, the motor must be rewound with Class H or N as applicable.

e. Motors not rewound with a sealed insulation system must be rewound as Class F, H or N insulation as applicable in accordance with Table 300-4-2.

f. Motors, insulated with a sealed insulation system that require rewind, should be rewound with a Class F sealed insulation system by a facility certified by NAVSEA. If rewind with a sealed system is not possible, the motor may be rewound with a Class F non-sealed insulation system, provided that the motor is rewound, again, at the earliest opportunity, with a sealed insulation system.

300-4.5.7.7 Rewinding Machines with Formed Coils. In rewinding ac and dc motor and generator armatures with formed coils, follow the procedure in paragraphs 300-4.5.7.1 through 300-4.5.7.5, except that materials given in Table 300-4-3 apply only if rewinding kits are not available. If formed coils for ac motors are to be provided as part of a sealed insulation system, see paragraph 300-4.5.7.6.

300-4.5.7.7.1 For submarine motor-generators the following materials and processing features apply to dc armature coils:

a. Coil insulation shall be mica-glass composite suitable for vacuum-pressure impregnation, such as G.E. 77986 or equal.

b. Armor tape shall be Dacron or fiberglass tape. If glass tape is used it must be heat pretreated to remove starch and lubricant to allow for subsequent resin penetration and wetting.

300-4.5.7.8 Rewinding Field Coils. Perform the procedure contained in paragraph 300-4.5.7.5. The old field should be removed from the pole piece and a new field coil installed. Usually, spare coils are available. If a new field coil must be made, all pertinent coil data must be recorded as the field coil is stripped down. A suitable coil form must be made for rewinding unless the coil is of the type that is wound directly on the pole. The rewinding should be done using materials in accordance with Table 300-4-2 if rewinding kits are not available. Perform the procedures contained in paragraphs 300-4.5.7.3 and 300-4.5.7.4.

300-4.5.7.9 Submarine Motor-Generator Sets. All rewound components shall be given vacuum-pressure impregnation using a solventless epoxy or polyester resin followed by dips in a solvent type modified polyester varnish, per MIL-I-24092, Class 155. The rewinding and VPI and varnish treatment of submarine motor-generator sets shall only be done by those shore activities that have been certified by Naval Sea Systems Command (NAVSEA). See Appendix C for the procedure to obtain certification for VPI refurbishment of submarine motor-generator sets.

Table 300-4-2 INSULATING MATERIALS FOR RANDOM WINDINGS[1]

Item	Insulation Class Materials to Use[2,3,7] F(155°C)	H(180°C) N(200°C)
Lead Wire	MIL-W-16878, EPDM	MIL-W-16878, PTFE or Silicone Rubber
Sleeving, leads and connections	MIL-I-3190, Class 155	MIL-I-3190, Class 200
Slot wedges, flat (machine to shape)	MIL-I-15037, GME (Glass-Melamine)	MIL-P-997, GSG
Varnish-solvent (Dip & Bake)	MIL-I-24092, Class 155 Grade CB Composition 1	MIL-I-24092, Class 200 Silicone
Varnish-solventless (VPI only)	MIL-I-24718	MIL-I-24718
Armor tape	Dacron[4]	MIL-Y-1140 (untreated glass[6])
Adhesive tape	MIL-I-15126 type GFT	MIL-I-19166
Coil side separator	MIL-I-24204 (polyamide paper) or MIL-I-24364 (Glass mat)	
Varnish-solventless (dip & bake)	MIL-I-24092/5	
Slot wedges, U shape	MIL-I-24204 (polyamide paper)	
Band Insulation[5]	MIL-I-24178 (Glass tape, semi-cured)	
Magnet wire[8]	J-W-1177 type M2 (polyamide film coated)	
Slot insulation (slot cell)	MIL-I-24204 (polyamide paper)	
Phase insulation	MIL-I-24204 (polyamide paper) or epoxy glass cloth	
Lacing, tying cord	MIL-T-43435, type V (aromatic polyamide)	
Sealed insulation system	See paragraph 300-4.5.7.6 and Appendix B	

NOTES:
1. Random windings consisting of ac motor stator and dc armatures.
2. See Appendix A for available sizes, types and grades.
3. For Class A, B and F insulation systems, use materials indicated for Class F materials.
4. Commercial grades, no applicable government specification available.
5. Insulating material used under metallic bands.
6. Untreated glass must be given a VOLAN treatment to remove the starches and oils used in weaving.
7. Materials specified in a NAVSEA certified rewind procedure shall be used in lieu of the materials in this table, when there is a difference between the two.
8. When the OEM drawings specify a different wire type, and it is known that the insulation system has not been upgraded, or when the wire removed can be typed, that wire type can be used in lieu of type M.

300-4.5.7.10 Reconditioning. If cleaning in the ship has failed to restore a machine's insulation resistance or there is significant evidence that cleaning in the ship will not be successful, a higher level of reconditioning must be chosen. The choice must be made between Reconditioning in Place and Reconditioning in the Shop:

a. Reconditioning in Place.
   1 Reconditioning in Place can be accomplished by IMA or Depot level facilities as well as by commercial facilities (often referred to as Industrial Cleaning). It consists of cleaning, drying (if necessary), inspection, varnishing and curing. The advantage of Reconditioning in Place is that an acceptable level of reconditioning is obtained without the cost of removing large equipment from the ship. The effectiveness of the cleaning and inspection process, however, is limited since, at best, the machine is only partially disassembled.
   2 The cleaning is normally accomplished by the high pressure spraying of a cleaning agent. Paragraph 300-4.5.5 provides guidelines for spraying water and cleaning compounds. Paragraph 300-5.2.3.4 provides the requirements for spraying of solvents. The cleaning compounds identified in paragraph 5.2.2 and the solvents identified in paragraphs 5.2.3.2 and 300-5.2.3.3 have demonstrated in the past that they do not harm

most insulation systems; however, the tests identified for each solvent should be performed to confirm compatibility. If cleaning compounds or solvents not identified in the above paragraphs are intended to be used, it must be demonstrated to NAVSEA prior to application that these materials are not harmful to the varnish or other insulating materials. The required safety precautions to be used when high pressure spraying with cleaning compounds are identified in paragraph 5.2.2. The safety requirements for solvent cleaning are shown in paragraph 300-5.2.3.3. The Material Safety Data Sheet for the material to be used should be referred to for additional safety precautions prior to using any cleaning compound or solvent.

3 After cleaning, drying should be accomplished in accordance with paragraph 300-5.3. The specific drying method selected will depend upon the drying equipment available and the constraints imposed by the activity accomplishing the reconditioning.

4 Varnishing should be accomplished in accordance with the guidelines of paragraph 300-4.5.8.

Table 300-4-3 SHOP RECONDITIONING OF MOTOR AND GENERATOR WINDINGS

Procedure	Class A, B, F, H and N Insulation
Step 1 Cleaning	See paragraphs 300-5.2.1 through 300-5.2.5.3.
Step 2 Drying	See paragraphs 300-5.3.1 through 300-5.3.8.
Step 3 Checking	All connections should be tightened, all wedges, bands, soldered connections should be checked and faults corrected where necessary.
Step 4 Prebaking	Put into oven at 150° C (302° F). Hold at temperature for 2-4 hours depending on size of equipment. Cool to approximately 40° C (104° F).
Step 5 Dipping	Immerse hot wound apparatus (40° C (104° F)) in organic varnish (modified polyester, Class 155, MIL-I-24092, grade CB or Class 180 grade CB) until bubbling ceases. Viscosity should be between 50 to 85 seconds.
Step 6 Draining	Drain and air dry for 1 hour. Rotate would apparatus during draining to prevent pocketing of varnish.
Step 7 Baking	Put into circulating type forced exhaust baking oven (two changes of air per minute) at 150° C (302° F) for 6 to 8 hours.
Step 8	Cool and check electrically.
Step 9	Repeat steps 5 through 8 if high level of insulation resistance is not obtained or if a satisfactory varnish build with a glossy surface is not obtained.

5 Industrial cleaning is normally provided as a package service encompassing all the above elements. The specific procedures used may vary in part from the above but should be fully documented and supported by past history of successful applications on similar commercial equipment.

6 Based on the cleaning material and process used, specific safety, health and environmental issues must addressed on local, state and federal levels. Different air quality regions have different volatile organic compound (VOC) requirements. The performing activity must comply with these requirements.

7 Regardless of whether the cleaning is done in ship or shop by a commercial activity, IMA or Depot level facilities, the cleaning process used shall contain requirements for the containment, collection, removal off-site and disposal of all waste generated throughout the cleaning process in accordance with current local, regional and federal regulations. The waste shall not be allowed to go into the bilge or public drains.

b. Reconditioning in the Shop. Reconditioning in the Shop provides the highest level of reconditioning since the machine is completely disassembled and thoroughly inspected, cleaned and varnished in accordance with Table 300-4-3.

300-4.5.7.11 Ball Bearings for Rewound Motors. Another important factor to be stressed is the type of ball bearing and lubricant to be used on rewound motors. See **NSTM Chapter 244, Propulsion Bearings and Seals** , on types of bearings and **Chapter 262, Lubricating Oils, Greases, Specialty Lubricants and Lubrication** , on lubricants.

300-4.5.7.12 Testing of Rewound Submarine Motor Generator. When submarine motor generators are rewound, the sequence of electrical tests listed in Table 300-3-9 should be followed.

300-4.5.7.13 Special Marking for Sealed Insulation System Motors and Submarine Motor-Generator Sets. A small nameplate identifying the repair activity shall be furnished on each refurbished equipment as detailed in Appendix B for ac induction motors and Appendix C for submarine motor-generator sets.

300-4.5.8 VARNISHING. The application of varnish will not permanently increase the insulation resistance or dielectric strength of insulating material and should not be used as a substitute for repairing or replacing defective insulation.

WARNING

Varnishes and thinners used in the dipping process are susceptible to ignition at ambient temperatures.

300-4.5.8.1 Varnish Application.

a. Varnish should never be applied to the whole or any part of a winding, either by dipping, spraying, or brushing, until the winding has been thoroughly cleaned and dried. Varnishing a dirty or moist winding seals in dirt or moisture and makes future cleaning impossible.

b. Varnish should be applied only when it will serve a useful purpose. The unnecessary and frequent application of varnish ultimately results in building up a heavy coating which interferes with heat dissipation and is likely to develop surface cracks.

c. The most satisfactory moisture-resistant coatings are obtained by dip-coating coils and apparatus in a suitable baking varnish. Spray coats are not equal in quality to those obtained by dipping. Spray coatings cover only those surfaces visible to the operator. Air-drying varnish films are less resistant to moisture than those obtainable with the better grades of baking varnish and are of lower dielectric strength and are intended primarily for applying varnish coverage to a localized area where the original coating is deficient or damaged. Consequently, a baking varnish applied in accordance with paragraph 300-4.5.8.2 through 300-4.5.8.4 should be used whenever feasible. However, in many instances facilities are not available for baking electrical equipment. This is particularly true in the case of large and heavy generators and motors such as are used in some electric propulsion installations. In such instances, revarnishing should be done by spraying with an air-drying varnish in accordance with the instructions given in paragraphs 300-4.5.8.5 and 300-4.5.8.6.

300-4.5.8.2 Baking Varnish. In general, the coils and windings of electrical equipment to be treated with a solvent type baking varnish, are required to have at least two dips and bakes in an approved varnish. The coils and windings of rotating wound components of electrical equipment to be treated with a solvent type baking varnish shall have at least three dips and bakes in an approved varnish. The coils and windings of electrical equipment to be treated with solventless type dipping varnish shall have at least three dips and bakes in an approved varnish. For Class A, B, and F insulated equipment, the varnish used is MIL-I-24092, Class 155 (clear baking). For Class H and Class N insulated equipment, the varnish used is a straight silicone Class 200 varnish of MIL-I-24092. There are special cases in equipment designs where other types of varnishes are used as black baking varnishes for some field coils and control coils, or clear air-dry varnishes for some large machines where it is not practical to bake. However, for reconditioning and replacement work by naval activities, it has been determined that the best adherence and most uniform results are obtained with the clear baking grades of varnish. See Appendix A for information concerning varnishes and thinner and Table 300-4-1 and Table 300-4-3 for procedures. See Figure 300-4-4 for a typical curve of insulation resistance as a function of curing time. A solventless dip varnish must be used when environmental regulations prohibit the use of solvent varnishes. It must be noted that most solventless varnishes will not overcoat windings that have been previously treated with any of a wide variety of solvent type varnishes used by Naval and commercial activities. NAVSEA is the point of contact for information on acceptable solventless varnishes. When using solventless dip varnishes, steps 1 through 5 of Table 300-4-1 and steps 4 through 7 of Table 300-4-3 may be modified to suit the varnish manufacturer's procedure-.Solventless dip varnishes should not be used to over-coat windings that have been previously treated with silicone varnish. Because of their chemistry, these windings offer a poor surface for revarnishing.

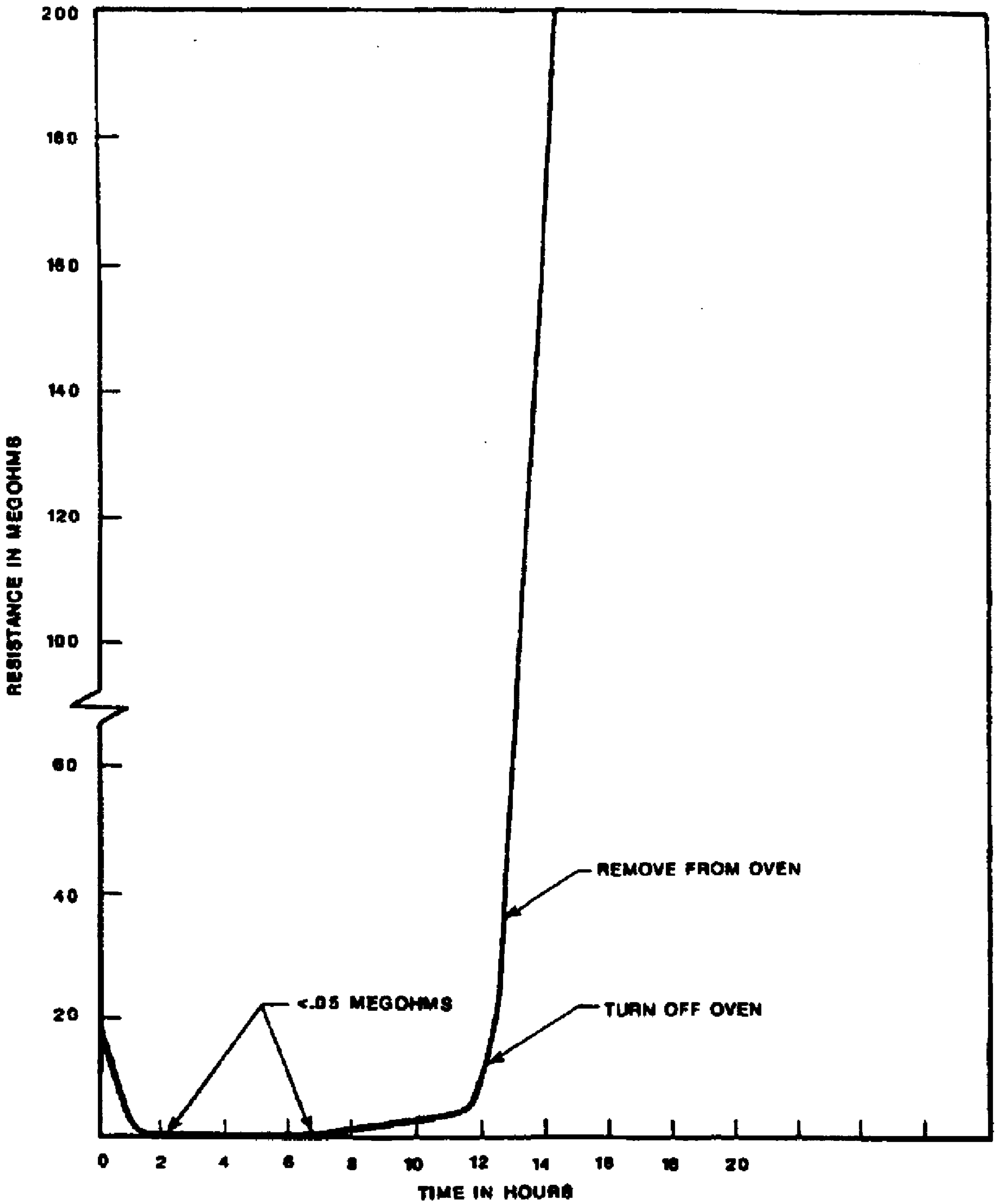


Figure 300-4-4 Insulation Resistance as a Function of Curing Time

300-4.5.8.2.1 Class 155 varnish shall be thinned with xylene. Prior to addition of thinner to the varnish, a small portion of the varnish shall be removed from the dip tank or container in a pint to quart glass jar or beaker for easy observation. Add an amount of thinner proportional to the amount intended to be added to the tank. After mixing thoroughly observe for signs of incompatibility such as small gelatinous formations or flocculation which can more readily be observed by dipping a spatula or glass slide into the varnish and watching the film during drainage. If there are no signs of incompatibility, the varnish in the dip tank can be thinned with the specific thinner tested. The varnish should not be thinned excessively to the point where the baked film is too thin to afford the necessary electrical insulation. Once every year, or more often if the varnish has been thinned considerably or is forming excessive film on the side of the tank, the addition of make-up varnish or thinner shall be stopped. At this point, the varnish in the tank should be used up to the extent practicable, the remaining varnish removed, and the tank cleaned. The varnish removed may be used again if found to be in good condition (past practice has indicated this is feasible). Varnish that has seeded or gelled in spite of precautions is unsuitable for use and should be discarded.

300-4.5.8.2.2 Varnishes used in the vacuum-pressure impregnation process (see paragraph 300-4.5.8.8) are solventless per MIL-I-24178 or in case Military Spec type resin is not available, use **NEMA Standard Publication No. RE-2, Electrical Insulating Varnish** . The solventless varnish should not be thinned with solvent under any conditions.

300-4.5.8.2.3 Mixing of varnishes of different brands, lots, or even of different conditions of aging such as varnish from the same lot from closed containers, occasionally may result in throw out, excessive thickening, or other signs of incompatibility. To insure compatibility between varnishes when mixed in the dip tank, small portions shall be mixed in a clear glass jar. The mixture proportion in the jar shall be equal to the proportion of the volume of varnish in the dip tank to the volume of varnish to be added. It shall be mixed thoroughly and allowed to stand at room temperature for 24 hours. At the end of that period, the mixture should be clear and show no signs of curdling, precipitation, or separation. If these requirements are met, the varnishes are considered to be compatible and can be mixed in the dip tank. Also, certain varnishes, not qualified under MIL-I-24092, that might be stocked or locally procured at some activities are likely to be incompatible with the MIL-I-24092 varnish or may be deficient in film properties.

300-4.5.8.2.4 Red-pigmented alkyd-resin-type varnishes shall not be used on any windings or coils for electrical equipment.

300-4.5.8.3 Control of Varnish for Dipping. Varnish for dipping and baking should be used in the dipping tank at a temperature of 25° C to 32° C (77° F to 90° F) whenever feasible. Normal fluctuations in varnish temperature caused by variation in room ambient temperatures need not be corrected; however, higher temperatures are undesirable because baking varnish viscosity increases with age at elevated temperatures. For the same reason, baking varnishes should be stored at temperatures not exceeding 40° C (104° F). Varnish should be maintained in accordance with Appendix F and as indicated by the manufacturer of the varnish.

300-4.5.8.3.1 Viscosity is a measure of the resistance of a fluid to flow. Simple viscosity measuring instruments are usually in the form of a cup and the viscosity of a fluid is expressed as the time (in seconds) required for a given volume to flow through a specific orifice. The No. 1 Demmler cup and the No. 2 Zahn cup (Figure 300-4-5) are typical examples.

300-4.5.8.3.2 For approximate viscosity measurements in the absence of conventional instruments, use a small can (about 1/2-pint capacity) with a small hole (not more than 1/8-inch diameter) in the bottom. Calibrate by filling the can with fresh water and observing the time required for the can to empty. Then dry the can and repeat with varnish. Water has a viscosity of 17 seconds by the Demmler No. 1 cup. Therefore, from this information, the viscosity of a liquid can be approximated by the formula:

Where:

$$V = \frac{17S}{R}$$

R = Reference value, the observed time in seconds for water

S = Observed time in seconds for varnish

V = Seconds viscosity - No. 1 Demmler cup

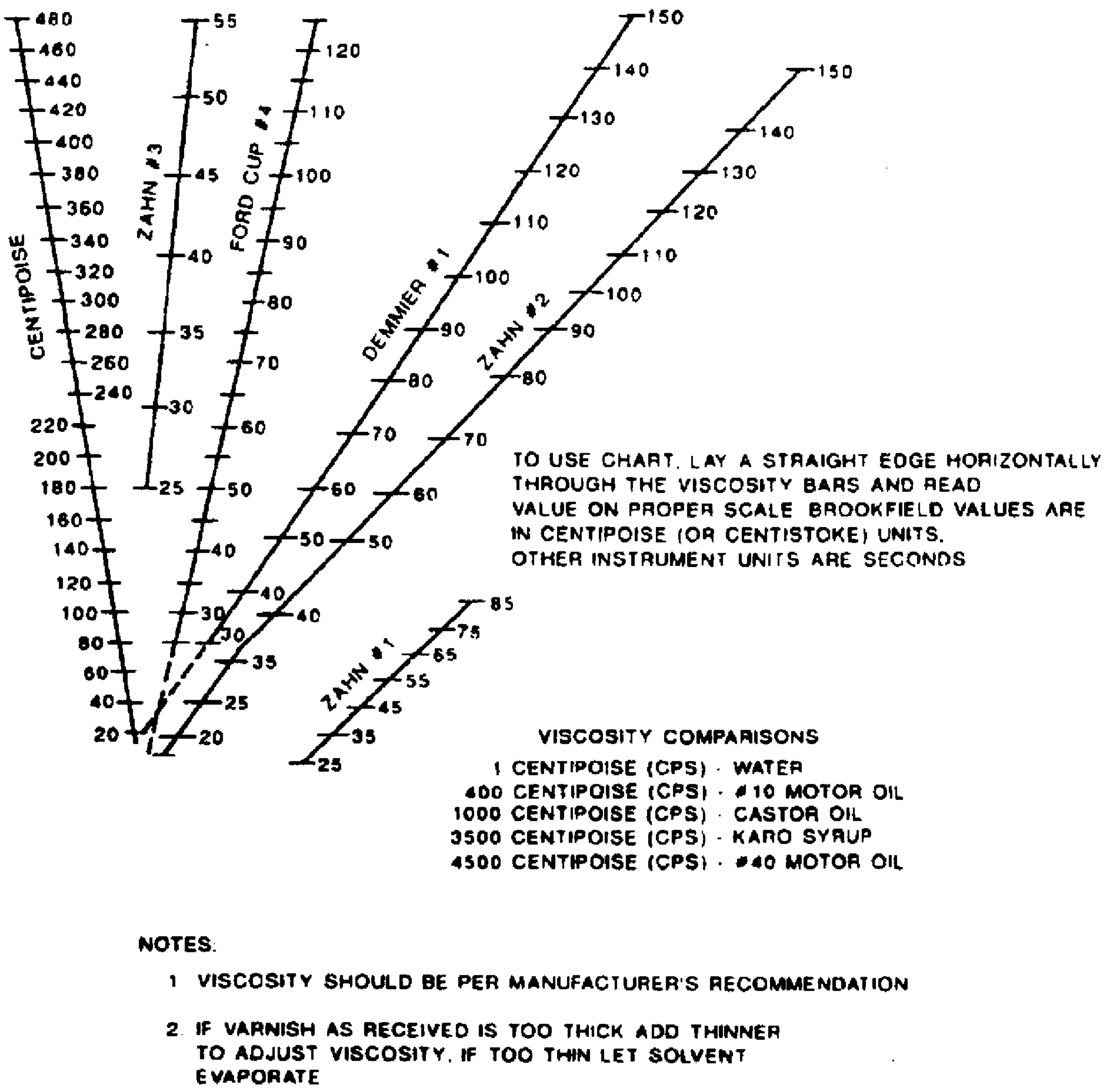


Figure 300-4-5 Varnish Viscosity Chart

300-4.5.8.3.3 Ordinarily, varnish for dipping apparatus should be 7 to 14 times the viscosity of fresh water by this crude test at a temperature of 22° C to 30° C (72° F to 86° F). Varnish which is above the desired viscosity should be thinned by using the thinner specified in paragraph 300-4.5.8.2.1.

300-4.5.8.4 Varnishing and Baking Procedure. After the equipment has been processed in accordance with the requirements of paragraph 300-4.5 for cleaning, drying, checking, and prebaking, it is ready for varnish treatment. The procedures shown in Table 300-4-1 or Table 300-4-3, as applicable, should be followed. The bake time indicated in the varnishing procedures begins when the equipment being varnished is at the specified baking temperature. The temperature of the equipment should be measured, while in the oven, using a thermocouple or other device of similar accuracy to determine when the equipment has reached baking temperature. Direct current armatures should be baked with the commutator end up.

300-4.5.8.5 Air-Drying Varnish. When it is necessary to use an air-drying instead of a dipping and baking varnish (see paragraphs 300-4.5.8.2 through 300-4.5.8.2.4, it should be a clear, air-drying varnish (grade CA) which conforms to MIL-I-24092. See Appendix A for varnishes and thinners. Thin with mineral spirits, if necessary, to maintain viscosity.

300-4.5.8.6 Spraying and Drying. Air-drying varnish should generally be used when varnish is to be applied by spraying, although baking varnish per MIL-I-24092 grade CB may be authorized for special applications. After the equipment to be varnished has been thoroughly cleaned and dried, the varnish should be applied in accordance with the following instructions:

a. Viscosity. Varnish for spraying should have a viscosity of 25 to 60 seconds at 25° C (77° F) when measured by the No. 2 Zahn cup, No. 1 Demmler cup, or the No. 4 Ford cup. When none of these cups is available, the viscosity can be measured approximately by the method described in paragraph 300-4.5.8.3.2. The viscosity of varnish as measured in this way should be about 3.5 to 9 times the viscosity of fresh water at a temperature of 22° to 30° C (72° to 86° F). Varnish which is above the desired viscosity should be thinned by using the thinner specified in paragraph 300-4.5.8.5.

b. Temperature. The equipment to be sprayed must be within the temperature range of 38° to 43° C (100° to 110° F). Equipment outside this temperature range cannot be treated satisfactorily. The varnish should be the same temperature as the equipment which is being sprayed.

c. Spraying equipment. An air cleaner should be installed in the air lines between the compressor and spray gun to remove oil and water from the line. An air regulator should also be installed to regulate the air pressure. Any standard spray gun and nozzle such as the De Vilbiss, Eclipse, Patsche, or Binks (such as shown in Figure 300-4-1) may be used. The choice of equipment will be determined by which is available and the type with which the operators can do the most satisfactory job. Experience in use usually determines which type can be used to the best advantage.

d. Air pressure. The pressure within the range of 20 to 70 lb/in^2 that gives the best results with the equipment employed is the air pressure that should be used. Practice tests should be made to select the air pressure and the values of other factors which will result in the most satisfactory spray job.

e. Spraying procedure. Before it is used, the varnish should be strained through several layers of cheesecloth to remove skin or dirt. When spraying, the spray gun should be held 6 to 12 inches from the work at all times in order to obtain the best results. It is essential that a smooth surface with a thin uniform coat be obtained. This depends to a great extent upon the skill and the experience of the operator. The spray stroke should be made with a free arm motion, keeping the motion of the gun parallel to the surface of the work at all points in the stroke. Holding the arm still and arcing the gun by moving the wrists results in uneven application and overspray at the ends of the stroke. The rate of spraying depends upon the ability of the operator, viscosity of the varnish, and atomizing pressure. These factors should be so adjusted that a full coat is deposited which does not sag when dried. An overlap should be used so that the main or central part of the spray overlaps the lower one-third of the preceding stroke. The spray gun should be moved uniformly at a constant speed. The material and air pressures should be adjusted to give a spray pattern 5 to 7 inches in length.

f. Number of coats. Two coats are usually adequate for satisfactory protection. In no case should more than three coats be applied.

g. Drying. The drying time to be allowed for each of the coats depends to a large extent upon the atmospheric conditions. The first coat of a two-coat application should be allowed to dry until tack-free, but not more than 24 hours. The final coat should be allowed to dry at least twice the time required for the material to reach a tack-free condition. Accelerated drying is permitted but in no case should the temperature of the work be allowed to exceed 70° C (158° F).

h. Precautions. Other precautions to be observed when spraying are as follows:

1 Spraying should not be done near open flames or heaters.

2 Adequate ventilation must be provided.

3 The operator should wear respirator and goggles.

4 Spray guns must be kept clean and in good condition. The instructions provided by the manufacturer should be followed.

5 Do not spray at low temperatures (below 20° C) or with the work at low temperatures.

6 Avoid the application of heavy films.

i. Aerosol spray. Aerosol spray cans of air dry varnish (3-1/2 hours) and lacquer (15 minutes) are available (see Appendix A and may be used when spray equipment is not available. The propellant is a petroleum distillate so the applicable safety precautions of subparagraph h and paragraph 300-5.2.3.3 shall be invoked.

300-4.5.8.7 Application of Varnish by Brushing. Application of air-drying varnish by brushing should be limited to reaching places that cannot be reached satisfactorily by spraying but that can be reached by a brush, or to touching up small spots which are of too limited area to warrant spraying, or to the application of varnish to isolated parts of a complete equipment where spraying might get varnish on parts where it is not desired.

300-4.5.8.8 Application of Varnish by VPI Method. Application of varnish by vacuum-pressure impregnation (VPI) depends on the availability of vacuum-pressure equipment and on the use of special types of varnishes. The equipment should be capable of maintaining a vacuum of 3 mm of mercury, or less, and a pressure with nitrogen or clean compressed air of 85 psi or more; e.g., 90 ± 5 psi. The varnish used should be without solvent, a single component epoxy type, have some thixotrophy (to prevent run out), and a long shelf life. Some Navy shore facilities have the equipment as do some commercial repair shops. Because of the special nature of the equipment and varnish needed, the VPI treatment has been limited to the repair of certain coils and windings where other methods have not been satisfactory and these have been handled on a case basis. The VPI method is designed to produce virtually void-free windings and complete surface coverage. All requests for use of this procedure should be referred to NAVSEA for decisions on application, materials, and procedure. Detailed guides have been developed for some types of rotating electrical equipment and may be useful in developing procedures for other types. See Appendix B for certification procedures for a sealed insulation system using VPI methods for squirrel cage induction motors and Appendix C for certification procedures for VPI treating of submarine motor-generator sets.

300-4.5.8.9 Application of Varnish by Trickle or Pour Method. Application of varnish by the trickle or pour method consists of pouring solventless varnish on a heated winding until the varnish has penetrated and gelled in place. The materials and procedure for the use of this process are in Appendix E. The quality assurance procedures and information for application of insulating varnishes to Navy electrical equipment are in Appendix F.

300-4.6 MAINTENANCE OF CABLES AND CABLE FITTINGS

NOTE

Where the Planned Maintenance System (PMS) is installed, preventive maintenance with the Maintenance Requirement Cards (MRC).

300-4.6.1 INSULATION RESISTANCE MEASUREMENTS. The purpose of cable maintenance is to keep insulation resistance high. Cables should be kept clean and dry, and should be protected from mechanical damage, oil, and salt water.

300-4.6.1.1 Ground Detector Systems. Passive ground detector voltmeter or ground detector lamp systems should be used hourly. This will show low resistance grounds on energized circuits. Active ground detector systems, such as those used on some submarines, will also indicate low insulation resistance. More precise measurement of insulation resistance should be made as frequently as indicated below on cable systems having passive ground detector systems and all other power and lighting systems using a 500-volt portable megger.

300-4.6.1.2 Frequency of Measurements. Insulation resistance measurements shall be made in accordance with the following:

a. Power and lighting cables including associated power transformers:
   1 Whenever physical damage has occurred
   2 Whenever there is evidence of a contaminant, such as oil or salt water, leaking on the cable
b. Degaussing system cables:
   1 Manually controlled degaussing coils utilizing rheostats and, where feasible, automatic and manual degaussing coils utilizing converters, shall be energized continuously when power is available, and insulation resistance shall be measured at one week intervals.
   2 In those instances where the insulation resistance is monitored by ground detector lights or voltmeter, insulation resistance measurements shall be conducted prior to energizing the coils if the coils have been secured for a period of 24 hours or more.
   3 Degaussing systems not applicable to the foregoing criteria shall be energized to a minimum of 3/4 maximum output at intervals not to exceed 1 week and shall operate at this value for a period not less than 8 hours. A system subjected to this weekly operation shall be given an insulation resistance measurement prior to energizing the degaussing coils. In the event that the degaussing system cannot be energized within the weekly interval, the policy of weekly insulation resistance measurements on such systems shall still apply.
   4 In cases where the compass compensating coil is disconnected or disassociated from the degaussing coil at the time of insulation resistance measurements, an additional insulation resistance measurement must be taken for the compass compensating coil.

300-4.6.2 INSULATION RESISTANCE OF CABLE ENDS. Low insulation resistance may be due to conditions at the ends of the cable whereby low resistance paths exist between the conductor or the connector lug attached to it and the sheath or armor. The metal armor or lead sheath should be cut away some distance back from the point where the impervious sheath is cut in order to provide ample creepage distance between armor or sheath and the terminal lug. This distance shall be at least 1-1/4 inches for ships service power cables, and at least 3 inches for electrical propulsion cables. In addition, it is essential that the surfaces of the insulation sheath exposed by the armor removal be cleaned of paint which is applied during the manufacture of the cable and which passes through the interstices of the armor onto the synthetic sheath, since such paint is conducting. On cables having a fabric braid in lieu of, or beneath the armor or lead sheath, the braid should also be removed from the vicinity of the terminal so that it does not contact the terminal as such braids are frequently impregnated with material which is partially conducting. Any moisture or dirt accumulated on the insulating surfaces at the cable ends may lower the insulation resistance and should be removed. When attempting to raise the insulation resistance of a cable, attention should be given first to terminal conditions.

300-4.6.3 MOISTURE IN CABLE. In spite of various provisions made to seal cable ends to prevent entrance of moisture, it may nevertheless manage to enter during long periods in which the cable has not been carrying current. Such moisture conditions are usually confined to the few feet near the cable ends. Generally, heat resulting from the current normally carried by the cable will drive the moisture out. While the insulation resistance may be lower than usual when first tested after such idle periods, it will gradually rise due to normal use. If excessive moisture in the cable is suspected, special treatment to drive it out may be warranted. The sealing means at the cable ends may be removed and the cable heated by passing current through the conductor, starting with a low current and gradually raising it until a cable sheath temperature of not more than 85° C (185° F) is attained. Care should be taken not to heat the cable too rapidly. The whole drying operation may require several days. If available, a low voltage for the heating current is desirable, but any voltage up to the rated voltage of the circuit may be used. When drying out two or more similar cables installed in close proximity to each other, or two or more conductors in a single cable, the conductors can be connected together at one end and a low voltage applied between the conductors at the other end. A welding generator, low-voltage degaussing generator, or other auxiliary generator which can be isolated for the purpose and the output voltage suitably controlled may be used for supplying this heating current.

300-4.6.3.1 Resealing of Cables. To prevent moisture-laden air from being drawn back into the cable when it cools after such a heating process, the cable ends must be immediately resealed when the drying-out current is removed and while the cable is still hot. Use type HF plastic sealer (conforming to MIL-I-3064, **Insulation, Electrical, Plastic Sealer**).

300-4.6.3.2 Cable Terminations. Some of the materials used to seal cable ends may be difficult to remove. It is relatively easy to open the ends of most single-conductor cables except those provided with solderless terminals of a type which are pressed on with high-pressure tools and which secure the impervious sheath as well as the conductor. Where this type of terminal is used, it may be necessary, unless extreme care is used, to cut the cable to remove the terminal. This should be done only if there is sufficient slack cable to permit the shortening which results

300-4.6.4 AGING OF CABLE. As cable ages, its insulation resistance tends to decrease somewhat due to natural changes in the insulation characteristics as well as some unavoidable moisture absorption. A gradual decrease in the successive values of insulation resistance measured during a period of months or years under equivalent conditions is normal and does not indicate the cable is unsatisfactory.

300-4.6.5 PHYSICAL DAMAGE TO CABLE. Lowered insulation resistance caused by physical damage to the cable (which breaks the impervious sheath or seriously deforms the cable) should be ascertainable by careful inspection. Cables should not be cleaned with wire brushes, scrapers, excessive solvent application, or by any other means which may damage the cable. Care must be exercised when cleaning structures near cables to avoid damage to the cables. Synthetic fire-resistant hydraulic fluid has a deteriorative effect on the impervious sheath of silicone-type cables. Care should be taken to avoid spilled or leaking hydraulic fluids from coming in contact with cables.

300-4.6.6 CABLE REPLACEMENT. Cable should be satisfactory for the service intended. In only a few cases it may be necessary to renew cable due to low insulation resistance resulting from other than actual physical damage. Such renewals are usually traceable to entrance of excessive moisture because of inadequate end seals. Subsequent tests on samples of such cable removed because of low insulation resistance have shown that actual breakdown of the insulation was not probable even with several times the rated voltage applied, and that such cable could have been continued in service without failure.

300-4.6.6.1 Corrosion or Physical Damage to Metal Armor. Rusting or corrosion of the metal armor or physical damage to the armor does not justify cable replacement provided that the impervious cable sheath remains intact. If, however, it is definitely established that the damage to the cable armor adversely affects inductive pick-up on neighboring cables, a braid shield should be applied.

300-4.6.6.2 Replacement Verification. If, after carefully checking the insulation resistance of cables by the methods described herein, and after using all practical means of improving insulation resistance which is considered low, the cognizant command considers that cable replacement is necessary, the insulation resistance of the cable in question should be measured by a repair activity, and the results obtained should be compared with the ship's records. If these measurements are below the safe minimum operating values shown in Figure 300-3-4 and Figure 300-3-5, the cable is unsatisfactory and should be replaced. On submarines, armored cable is preferred for a replacement if available in the cable type required.

300-4.6.6.3 Marginal Values of Insulation Resistance. Judgment should be exercised in the replacement of cables showing marginal values of insulation resistance, particularly those cables where the insulation resistance measurements do not indicate a continuing downward trend, and have remained fairly constant (or show an upward trend) over a period of time with readings in a range below or near the limits of Figure 300-3-4 and Figure 300-3-5 since in most such cases actual breakdown of the insulation is not probable, and the cable may be continued in service without failure. The limits of Figure 300-3-5 were established arbitrarily with what was considered to be an adequate safety factor. It is, therefore, quite possible for cable to continue in service without failure with values of insulation resistance below these limits.

300-4.6.7 SHIPBOARD ELECTRICAL CABLE AND CABLEWAY INSPECTION AND REPORTING PROCEDURE. Shipboard electrical cable deficiencies identified fall into three categories:

a. Immediate Hazard. Those items which are, or have the immediate potential to be, personnel safety hazards, electrical fire hazards, or which negate firebreak integrity are considered CATEGORY 1 items.

b. Potential Hazard. Those items which require corrective action to ensure continued reliable safe performance or maintain watertight integrity but are not of immediate danger to personnel or equipment are considered CATEGORY 2 items.

c. Nonhazardous. Those items which are not hazardous to personnel and equipment but are not in compliance with approved standard installation practices are considered CATEGORY 3 items.

300-4.6.7.1 Procedure. The inspection criteria for electrical cables and cableways are shown in Table 300-4-4.

a. New electrical cable plans and/or installation, regardless of planning or installing activity (private or public), will be in accordance with current NAVSEA technical requirements as set forth in DOD-STD-2003, **Electrical Plant Installation Standard Methods for Surface Ships and Submarines** .

b. Authority for waivers to the above document shall be vested in the cognizant Ship Program Manager with a copy of the waiver to Chief Engineer (CHENG).

c. Special inspection teams will be established to inspect and repair shipboard cable installations and members of the team shall be qualified.

d. Shipboard electrical cable installations will be inspected during the Pre-Overhaul Test and Inspection (POT&I) process or preavailability inspections conducted prior to the ship undergoing an industrial availability longer than 6 weeks. Inspections shall be conducted using the inspection criteria provided in Table 300-4-4. CATEGORY 1 items identified during a POT&I will be reported to the ship's Commanding Officer. Ship's force should start immediate corrective action on category 1 items. Ship's force will ensure that all CATEGORY 1 and CATEGORY 2 deficiencies are documented for correction during next availability. Those CATEGORY 1 items not repaired at the availability start will be screened for repair during the upcoming availability. For availabilities longer than 6 weeks, the remaining CATEGORY 1 and CATEGORY 2 items will be screened for repair. The Type Commander (TYCOM) may screen these items to any qualified work force (i.e., Shore Immediate Maintenance Activity (SIMA), shipyard, ship's force, or other).

e. Those maintenance or modernization availabilities not receiving a POT&I or Find and Fix inspection by a qualified Fleet or Industrial Activity Electrical cableways repair team within 12 months of the availability shall require an **inspect and report** of electrical cableway deficiencies immediately upon arrival for the availability. For these inspections the TYCOM may use any team qualified in accordance with paragraph 300-4.6.7.1c above. All CATEGORY 1 and CATEGORY 2 deficiencies shall be screened for correction in accordance with availability length as stated in paragraph 300-4.6.7.1d.

f. Unused (dead-ended) cable, for which no known requirement exists, to be determined by ship's force, shall be removed during the next industrial availability. The term **remove where practical** in any document referring to the removal of **dead-ended** cable shall be eliminated.

   1 After cable removal, vacated stuffing tubes, multiple cable penetrators (MCPs), kickpipes, etc., shall be blanked off in accordance with requirements of DOD-STD-2003.

   2 A request for waiver shall be submitted in accordance with NAVSEAINST 9304.1 when **dead-ended** and unused cables cannot be removed. This request should be marked for the attention of the cognizant NAVSEA Ship Program Manager. All unused electrical cable not removed shall be disconnected from all sources of power, end-sealed in accordance with paragraph 300-4.6.7.1a, and documented in the current ship maintenance plan.

g. NAVSEA is the point of contact for issues involving implementation of the electrical cableway program.

300-4.6.8 CABLE REPAIR AND SPLICING. Cable repair may be made by ship's force. Cable splices should not be made by ship's force except in an emergency. Where such splices are made, they should be replaced at the earliest opportunity by a continuous length of cable or by an approved splice installed by a repair activity. Prior to cutting a cable, confirm that the cable has been identified as the cable intended to be cut, and verify that the cable is deenergized. Paragraphs 300-4.6.8.1 through 300-4.6.8.2.3 contain guidance criteria for cable repair and splicing. These criteria are intended for use by repair activities in determining when and where repairs and splices should be permitted. Exceptions to the criteria may be taken, except where NAVSEA 08 approval is required, when in the opinion of the supervising authority the exception is in the best interest of the Navy.

Table 300-4-4 INSPECTION CRITERIA FOR ELECTRICAL CABLES AND CABLEWAYS

Item	Criteria	Category
I.	CABLES	

Table 300-4-4 INSPECTION CRITERIA FOR ELECTRICAL CABLES AND CABLEWAYS - Continued

Item	Criteria	Category
	A. Installation	
	1. Minimum bend radius kinked to point of deforming the cable.	1
	2. Minimum bend radius exceeded; the cable rings out and meggers satisfactorily.	3
	3. Equipment connector supporting weight of cable (more than 36 inches of cable from last support to end use equipment), (18 inches from shock mounted motors).	1
	4. Cables run on or near hot objects (steam or exhaust pipes, griddles, oven, etc.).	1
	5. Cable run outside of hangers.	2
	6. Lack of slack at expansion joints.	2
	7. Excess slack between hangers, (Minimum distance of 6’4″ between deck and cables).	2
	8. Excess cable slack stored in wireway.	2
	9. Non-low smoke cable installed in new construction.	1
	B. Damage	
	1. Bulging, bubbling or discoloration of cable jacket (evidence of overloading, overheating or hot spots).	1
	2. Bulging, bubbling or discolored cable jacket; but cable rings out and meggers satisfactory.	2
	3. Cable chafed or cut through outer jacket only.	2
	4. Cable chafed or cut through inner wire insulation.	1
	5. Cable pulled out of equipment/junction box penetrations and leads exposed (greater than 30V).	1
	6. Less than 30V (damaged cable).	2
	7. Armored and unarmored cables in contact at an oblique angle causing chafing of unarmored jacket.	2
	C. Deadended	
	1. All cables dead-ended and not properly end sealed.	1
	2. Cable deadended and end sealed properly.	2
	D. Spliced	
	1. Improper materials/methods used for splicing, or evidence of loose joints.	1
	2. Individual conductor joints not staggered within splice of multi-conductor cable.	2
	3. Splice located in bend of cable.	2
II.	BANDING	
	A. All Cable Runs	
	1. Banding cuts cable outer jacket (banding too tight).	1
	2. Banding compressing outer jacket (banding too tight but not cutting jacket).	2
	3. Bailing wire left on cables.	1
	4. Bands cut and left in wireway.	1
	5. Channel rubber not installed where required.	2
	B. Horizontal Cable Runs	
	1. Banding not installed at breakout hangers before and after penetrations or at change of direction of wireway.	1
III.	CABLEWAYS	
	1. Cable hangers or hardware cutting into the cable jacket.	1
	2. Cable hangers missing (Cable hangers are required at least every 32 inches except that hangers for multiple tier overhead aluminum decks shall be spaced every 16 inches).	2

Table 300-4-4 INSPECTION CRITERIA FOR ELECTRICAL CABLES AND CABLEWAYS - Continued

Item	Criteria	Category
	3. Inadequate cable support (hangers, hardware, tiers, or cable straps missing) or welds cracked.	2
	4. Inverted ″T″ bar hangers installed horizontally on bulkheads.	2
	5. Overloaded cable hangers.	3
	6. Maximum no. of tiers exceeded.	2
	7. Inadequate fastener length.	2
	8. 1/2″ clearance between cable run and hanger above or structure not provided.	
IV.	EQUIPMENT	
	A. Covers	
	1. Power junction box or equipment connection point covers loose or missing.	1
	2. Sound powered junction box or equipment connector point cover loose or missing.	2
	B. Mounting	
	1. Cable supporting the weight of equipment (power junction boxes, lighting fixtures switch boxes, etc.)	1
	2. Cable supporting the weight of low voltage equipment (sound powered junction boxes, equipment, etc.) and cables pulled out of box.	2
	C. Cable Entrance	
	1. Watertight penetrators not utilized for entrance to watertight power equipment enclosures.	1
	2. Drip loops, drip shields or bottom penetration not utilized for entrance to non-watertight drip proof power equipment.	1
	3. Drip loops, drip shields, or bottom penetration not utilized for entrance to non-watertight drip proof sound powered equipment enclosures.	2
	4. Watertight penetrations not utilized for entrance to watertight sound powered equipment enclosures.	2
	5. Cable can be moved in and out of tube. Improperly packed or not packed	1
	6. Nylon tube base loose in enclosure. O-ring missing.	1
V.	DECK/BULKHEAD PENETRATIONS	
	A. Non-Watertight Deck or Bulkhead Cable Penetration	
	1. No plastic sealer around cable or stuffing tubes which are exposed to weather. Note: If plastic sealer is installed at locations other than those exposed to weather, it is not required to be removed.	2
	2. No plastic sealer around cables through collars.	1
	3. Cable dead-ended in deck/bulkhead watertight penetration and not end sealed properly.	1
	4. Chafing protection not installed at non-watertight deck or bulkhead cableway penetrations.	2
	5. Chafing ring overloaded.	3
	6. Inadequate chafing protection and damage evident.	1
	B. Watertight Deck or Bulkhead Cable Penetrations	
	1. No plastic sealer around cable or stuffing tubes which are exposed to the weather. Note: If plastic sealer is installed at locations other than those exposed to weather, it is not required to be removed.	2
	2. Cable dead-ended in deck/bulkhead watertight penetration and not end sealed properly.	1

Table 300-4-4 INSPECTION CRITERIA FOR ELECTRICAL CABLES AND CABLEWAYS - Continued

Item	Criteria	Category
	C. Cable Entrance	
	1. Stuffing tube or kickpipe not utilized (cable installed without tube).	1
	2. Unused stuffing or kickpipe not plugged.	2
	3. Stuffing tube or kickpipe assembly incomplete (missing gland nut, packing, or pipe connector).	2
	4. Stuffing tube assembly incorrect (improper packing).	2
	5. Stuffing tube or kickpipe too small for size of cable.	2
	6. Multiple cable in a single stuffing tube or kickpipe.	2
	7. Stuffing tube or kickpipe damaged to point where complete assembly not possible (cracked welds, damaged threads, out-of-round, etc.) if firestop material is installed.	2
	D. Watertight Deck or Bulkhead Penetrations Utilizing Multiple Cable Penetrations	
	1. Insert blocks, compression bolts or filler blocks missing.	1
	2. Improper size blocks used for size cable installed violating watertight integrity.	2
	3. Improper use for RTV to seal MCP blocks.	2
	4. Dead-ended cables not end sealed or not end sealed properly.	1

300-4.6.8.1 Cable Repair. A cable repair is the restoration of the cable armor or the outermost cable sheath or both. All cables may be repaired except:

a. Cables for repeated flexing service (see b)

b. Portable cables (shore power cable may be repaired)

c. Dc bus tie cables on nuclear submarines, unless approved by NAVSEA 08

d. Reactor plant system cables, unless approved by NAVSEA 08.

300-4.6.8.1.1 Cable repair shall be in accordance with DOD-STD-2003-1, **Electric Plant Installation, Standard Methods for Surface Ships and Submarines (Cable)** , except that other methods approved by the supervisor may be used if standard methods cannot be applied. The installing activity shall obtain approval from the supervisor prior to a cable repair. No record of cable repair is necessary.

300-4.6.8.2 Cable Splicing. A cable splice is the restoration on any part of a cable that cannot be restored by a cable repair. All cables may be spliced except:

a. Radio frequency coaxial types

b. Antenna system cables (both inboard and outboard)

c. Cables for repeated flexing service (see d)

d. Portable cables (shore power cables may be spliced)

e. Cables in voids

f. Cables in normally inaccessible spaces

g. Cables in hazardous spaces (i.e., spaces requiring explosionproof enclosures)

h. MDU (conforming to MIL-C-915/12) cable exposed to the weather

i. Dc bus tie cables on nuclear submarines unless approved by NAVSEA 08

j. Reactor plant system cables unless approved by NAVSEA 08.

300-4.6.8.2.1 No more than two splices should be allowed in a cable.

300-4.6.8.2.2 Cable splices shall be in accordance with DOD-STD-2003-1 except that other methods approved by the supervisor may be used where standard methods cannot be applied.

300-4.6.8.2.3 The installing activity shall obtain written approval from the supervisor prior to making a cable splice. The request for a splice shall contain:

a. Cable designation

b. Cable type and size

c. System or component supplied

d. Location of the splice (compartment, area, and so forth)

e. Length of cable from each end to the splice

f. Method to be used for the splice

g. Reason for the splice.

300-4.6.9 DEAD-ENDED CABLES. Dead-ended cables result from alterations made when time does not permit removal or when removal of cable may result in damage to other cables. Dead-ended cables shall be disconnected at both ends and the ends sealed in accordance with DOD-STD-2003-1. They increase dead weight (frequently at high levels), lower damage resistance, and increase the difficulty of cable identification, removal, maintenance, and alteration. They should be located, identified, and removed at the first opportunity, if such removal can be accomplished without damage to other cable in the vicinity. After removal of the cable, the stuffing tube is to be blanked off by a sealing plug in accordance with DOD-STD-2003-1.

300-4.6.10 CABLE FITTINGS. The integrity of fittings used with Navy shipboard cables involves several factors which must be considered in connection with their maintenance. Unlike piping and shafting, electric cables are resilient, cannot withstand high packing pressures, and are used with specially designed stuffing tubes and packings which employ moderate pressures and obtain a seal chiefly because of the plastic nature of the sealing compound. Even with these packings, loose seals occasionally develop due to any one or more of several factors, such as loosening of the gland nuts, flowing of the soft plastic packing, or necking of the cables. However, there is only a remote chance of the gland nuts loosening or backing off after the compartment in which they are located has been painted, since the paint over the gland nuts will tend to keep them from turning. Loosening of the seal is more often caused by flow of the soft plastic packing into the interstices of the cable armor, or by depression or necking of the cable itself because of excessive packing pressure. Continued setting up or tightening of stuffing tube gland nuts beyond that required to maintain watertightness is undesirable since with each setting up and equalization of pressure further necking of the cable occurs. Moreover, successive tightening of gland nuts may cause a lowering of the cable insulation resistance due to compression of insulation near the stuffing tubes and if carried to excess, may ultimately damage the cable sheath. It is, therefore, necessary that care be taken when setting up gland nuts to avoid excessive packing pressure. Procedures for working with stuffing tubes and packing assemblies are found in DOD-STD-2003-3, **Electric Plant Installation, Standard Methods for Surface Ships and Submarines (Penetration)** .

300-4.6.10.1 Stuffing Tubes. It is particularly important that care be taken with stuffing tubes which are periodically or continuously exposed to high temperatures because high temperatures soften the cable sheath and increase the likelihood of cable necking. When making periodic compartment air tests on shipboard (see **NSTM Chapter 9880, Damage Control; Compartment Testing and Inspection**), it is preferable that no stuffing tube gland nuts be tightened except those which have obviously loosened or backed off, or unless the air test shows leakage through the stuffing tubes. When stuffing tube gland nuts must be tightened, an additional turn of soft packing cord should be inserted if it is at all practical. Careful observance of this procedure should result in satisfactory watertightness of the stuffing tubes without impairing the performance of the cable. The same procedures are applicable to multicable transits.

300-4.6.10.2 Hangers. The bolts and nuts which secure cable hangers, connection boxes, and wiring appliances to bulkheads and other supports may become loosened and lost because of vibration. Since loose electrical equipment is a hazard to personnel as well as costly in material maintenance, all hands should be trained in recognizing and reporting such conditions on a continuing basis so that maintenance measures can be taken.

300-4.6.10.3 End Seals. Heat and flame resistant cables used on shipboard have a watertight sheath to keep water from reaching the electrical insulation. This sheath can serve as a conduit in carrying considerable quantities of water from a flooded to an unflooded space. Water which enters the sheath through a puncture or through an open cable end in the flooded space travels through the interstices between the strands of the conductors because of the head pressure set up in the flooded space. At the far end of the cable, the discharged water may cause short circuits or grounds in the equipment to which the cable is connected. There is, therefore, a definite possibility that flooding of one compartment may result in extensive damage to electrical equipment in other compartments. To prevent this trouble, cable ends are sealed where necessary to prevent the entrance and discharge of water from cable ends. Additional cables believed to require this protection should be reported for investigation and correction during overhaul periods.

300-4.6.10.3.1 Great care should be exercised when working around cables and switchboards to prevent damage to cable end seals, and frequent inspections should be made for visual evidence of defects in the seals. If any holes are found in the synthetic tubing used at end seals, a temporary repair should be made by wrapping the tubing tightly with several layers of synthetic tape, half lapped, and serving with cord over the tape. Other defects which may be noted should be repaired as effectively as available materials and equipment permit. All cable end seals to which temporary repairs have been made should be tagged and scheduled for permanent repair at a naval shipyard or shore base at the earliest opportunity.

300-4.6.10.3.2 Currently manufactured cables are required to have an impregnant between the strands and in the material between the conductors and the inside of the sheath. This practice has resulted in a material decrease in the amount of water that can flow through a cable but has not accomplished complete watertightness. Cable end sealing is still required for these newer cables.

300-4.6.11 CABLE MARKING TAGS. All permanently installed ships cables are identified by metal tags or plates upon which the cable designation is embossed so that the cables may be readily identified for purposes of maintenance and replacement. Information on cable designations is contained in (1) Design Data Sheet, DDS 305-1, **Designations and Marking of Electric System;** and (2) **Section 305, Electrical and Electronics Designating and Marking, of General Specifications for Ships of the United States Navy** (NAVSEA S9AA0-AA-

SPN-010/GEN-SPEC), (NSN 0910-LP-007-4100). Letters and numbers are used to form the complete cable designation in conformance with DDS-305-1 and Gen-Spec section 305. Electrical wiring plans on a ship give the exact designation for each cable.

300-4.6.11.1 Letter Identification. Letters now being used to identify cables for different services are given in Table 300-4-5.

Table 300-4-5 CABLE SERVICES IDENTIFICATION LETTERS

Services	**Designations**
Cathodic protection	CPS
Control, power plant and ship	K
Degaussing	D
Electronics	R
Fire control	G
Interior communications	C
Lighting, emergency	EL
Lighting, navigational	N
Lighting, ship service	L
Minesweeping	MS
Night flight lights	FL
Power, casualty	CP
Power, emergency	EP
Power, propulsion	PP
Power, ship service	P
Power, shore connections	PS
Power, special frequency	SF
Power, weapon system	WP
Power, weapon system, 400 Hz	WSF

300-4.6.11.2 Additional Identification. Other letters and symbols are used with these basic cable service identification letters to form the complete cable designation which gives the cable's source, service, and designation. Typical markings for power systems cables from a generator to a load, and the meanings of the symbols, are as follows:

a. Generator cables: 6SG-4P-6S
   6SG-Fed from ship service generator No. 6
   4P-450-volt power cable
   6S-Supplying ship service switch-gear group No. 6

b. Bus feeder: 6S-4P-31
   6S-Fed from ship service switchgear group No. 6
   4P-450-volt power cable
   31-Supplying load center switchboard No. 31

c. Feeder: 31-4P-(3-125-2)
   31-Fed from load center switchboard No. 31
   4P-450-volt power cable
   (3-125-2)-Supplying power distribution panel located on third deck, frame 125, port side

d. Main: (3-125-2)-4P-C

(3-125-2)-Fed from power distribution panel located on third deck, frame 125, port side
4P-450-volt power cable
C-Indicates that this is the third cable from the panel

e. Submain: (3-125-2)-1P-C1
(3-125-2)-Fed from power distribution panel located on third deck, frame 125, port side
1P-120-volt power cable
C1-Indicates first cable fed (through a transformer) by the main listed just above

f. Branch: (3-125-2)-1P-C1B
(3-125-2)-Fed from power distribution panel located on third deck, frame 125, port side
1P-120-volt power cable
C1B-Indicates second cable fed by the submain listed just above

g. Subbranch: (3-125-2)-1P-C1B2
(3-125-2)-Fed from power distribution, panel on third deck, frame 125, port side
1P-120-volt power cable
C1B2-Indicates second cable fed by the branch listed just above

300-4.6.11.3 Interior Communication and Fire Control. For interior communication and fire control circuits see **NSTM Chapter 430, Interior Communication Installations** .

300-4.6.11.4 Tag Location. Cables are tagged as close as practical to each point of connection, on both sides of decks,bulkheads, and other barriers. Cables located wholly within the same compartment in such a manner that they can be readily traced, need not be tagged.

300-4.6.11.5 Tag Availability. Cables which are not tagged in accordance with the foregoing should be provided with cable tags, embossed with the appropriate cable designation. Ships not equipped to provide and emboss their own cable tags may obtain them from a tender, repair ship, or a repair activity.

300-4.6.11.6 Tag Maintenance. Cable marking tags should be maintained intact at all times. Tags should be securely fastened to cables and so positioned on the cable that they are readily visible.

300-4.6.12 PERIODIC TESTS AND INSPECTIONS. Where PMS is installed, the MRCs shall determine frequency and procedures for performing periodic tests and inspections. Otherwise, conduct tests and inspections as frequently as indicated in paragraph 300-4.6.1.2 by methods outlined in paragraphs 300-3.2.1 through 300-3.2.8.3.

a. Every watch. Use the ground detector voltmeter or ground detector lamps to check for grounds.

b. Quarterly. Measure insulation resistance of cables with insulation resistance measuring instrument.

300-4.7 MAINTENANCE OF ELECTRIC GENERATORS AND MOTORS

NOTE

Where PMS is installed, conduct preventive maintenance in accordance with MRCs.

300-4.7.1 GENERAL. The essential points in the maintenance of electric generators and motors are:

a. Keep insulation clean and dry.

b. Keep electrical connections tight.

c. Keep machines in good mechanical condition.

300-4.7.2 LOOSE METAL AND SOLDER. Keep all small pieces of iron, bolts, and tools away from the machines. Where it is necessary to do any soldering, make sure that no drops of solder get into the windings and that there is no excess of solder on soldered joints which may later break off due to vibration and fall into the windings.

300-4.7.3 BOLTS AND MECHANICAL FASTENINGS. Care should be exercised not to disturb the commutator clamping bolts on dc machines. Interference with these may make it necessary to turn or grind the commutator to restore it to service. Other bolts and mechanical fastenings on both the stationary and rotating members should be tightened securely when the machine is erected, checked after the equipment has run for a short time, and thereafter checked at regular intervals to make sure that they are tight. Particular attention should be given to the bolts used to clamp any insulation.

300-4.7.3.1 Rotor Hardware. If an inspection of a rotor shows that there is looseness of keys, bolts, or other fastenings, a check should be made for evidence of damage due to this looseness. Such looseness may result in worn dovetail keys, damaged windings, or broken dovetails on the end plates. Two or three drivings usually will insure the tightness of the keys, but nevertheless they should be checked regularly.

300-4.7.3.2 Armature Banding. The banding wire on dc armatures should be checked at regular intervals to make sure that it is tight.

300-4.7.3.3 Bearings. The outboard bearing on some generators (both ac and dc) is electrically insulated from the frame; or the bearing pedestal is insulated from the base and the bearing oil piping to prevent the flow of shaft currents through the bearing. In the former case, insulation is accomplished by means of a shell of insulating material installed between the bearing shell and the bearing housing. In the latter case, the bearing insulation is accomplished by using insulating shims under the pedestal and insulated hold-down bolts and dowels. Also insulated couplings are provided in the bearing inlet and outlet oil piping flanges (for force feed bearings). Special attention should be taken to insure that this insulation is not damaged or that conducting paths around this insulation are not inadvertently provided. For instance,care should be taken when painting machines furnished with insulated pedestals not to paint over the insulating shims, washers, and oil piping couplings. Bearing currents, if of sufficient magnitude, will rapidly ruin a bearing. These currents are caused by electromotive force generated in the shaft and structural parts of a generator unless it is carefully designed and constructed to minimize their occurrence. An insulated bearing (or pedestal) breaks the circuit and protects the bearings from damage so long as the insulation is effective.

300-4.7.4 ELECTRICAL CONNECTIONS. All electrical connections (particularly terminals and terminal board connections) should be inspected at frequent intervals to ensure they are tight. Loose connections result in increased contact resistance and increased heating which may result in breakdown. Use lock nuts, lock washers, or other means to lock connections which tend to become loose because of vibration. Inspect soldered terminal lugs for looseness or loss of solder, and tighten solderless terminal lugs occasionally. When electrical connections are opened, clean all oil and dirt from contact surfaces before reconnecting. If the contact surfaces are uncoated copper, sandpaper and clean immediately before joining. If the contact surfaces are silver-plated, do not use sandpaper. Use silver polish or a cloth moistened slightly with an approved cleaning agent. Coat the finished joint with insulation varnish. Steel bolts for making electrical connections should be zinc plated. Make sure that exposed electrical connections are adequately insulated to protect against water and moisture and injury to personnel. This applies especially to exposed connections at terminal straps extending outside the frames of propulsion motors and generators. Motor connection box leads, except for propulsion units, should be assembled as shown in figure 1B10 of DOD-STD-2003-1 (Navy).

300-4.7.5 CLEANLINESS. Keep the interior and exterior of machines clean and free from dirt of any kind, salt, lint, oil, and water, and especially carbon or copper dust. See paragraphs 300-4.5.1 through 300-4.5.5 for instructions on cleaning methods.

300-4.7.5.1 Filter Cleaning and Equipment Inspection. Permanent-type air filters should be cleaned or replaced quarterly. After a machine has been cleaned, the windings should be inspected for visual evidence of mechanical damage to the insulation, or damage caused by excessive action of any solvents used in cleaning. See paragraphs 300-4.5.7 through 300-4.5.8.9 for instructions on the repair and revarnishing of damaged insulation.

300-4.7.5.2 Equipment Protection During Overhaul. Each overhaul yard should insure that adequate protection is provided to electrical machinery during overhaul periods, particularly electrical rotating machinery located in spaces where yard personnel are working. Electrical rotating machinery not required to be operated during the overhaul period should have openings sealed with a flexible waterproof barrier material which should not be removed until after the space has been restored to operational condition. Where operation of electrical rotating equipment is necessary in spaces where overhaul work is scheduled, protective screens of suitable filter material should be installed. Filter media carried in Navy stock number NSN 9330-00-965-0481 or 9330-00-442-2730 have been found to be suitable. NSN 9330-00-442-2730 should be used for conditions which are extremely dirty or if the dirt is fine. Machine temperatures should not be allowed to rise above the design rating and filters should be changed as often as necessary to prevent the entrance of oil, water, metal shavings, abrasives from grinding, and dirt. Upon completion of overhaul and prior to operation without filters, extreme care should be taken to ensure that all dirt, abrasives, chips, and so forth, are removed from pockets in the foundations in the vicinity of the air intake of electrical rotating machinery.

300-4.7.6 BEARINGS. See **NSTM Chapter 244, Propulsion Bearings and Seals** , for general information on ball bearings, including cleaning and lubrication. Preventive maintenance of sleeve bearings requires periodic checks of bearing wear, lubrication, condition, and operation of oil rings, and condition of the bearing surfaces.

300-4.7.7 BRUSHES. Proper maintenance practice will go far towards eliminating brushes as a frequent cause of failure. See CAUTION paragraph 300-4.5.7.

300-4.7.7.1 Brush Grade and Adjustment. The correct grade of brush and correct brush adjustment are necessary to avoid commutation trouble. For good commutation, use the grade of brush shown on the drawing or in the technical manual applicable to the machine, except where NAVSEA instructions issued after the date of the drawing or technical manual (such as the instructions for brushes to be used in electrical propulsion and magnetic minesweeping equipment) state otherwise. In such cases, the NAVSEA instructions should be followed. In the case of propulsion and magnetic minesweeping equipment, only one grade of each of two different brush manufacturers is permitted for any machine. This restriction on brush interchangeability is based on the vital nature of the machines involved and on the impracticability of factory testing these machines while operating with several manufacturers' grades which have been qualified under any one of the six military grades. Never mix different manufacturer's brushes, or different types or grades of brushes from the same manufacturer. Rapid brush wear could result from a mismatch of brushes.

300-4.7.7.1.1 All brush shunts should be securely connected to the brushes and the brush holders.

300-4.7.7.1.2 Brushes should move freely in their holders but should not be loose enough to vibrate in the holder.

300-4.7.7.1.3 The following brushes should be replaced with new brushes, the replacement being preceded by cleaning all dirt and other foreign material from the brush holder:

a. Brushes which are worn or chipped to such an extent that they will not move properly in their holders.
b. Brushes which have damaged shunts, shunt connections, or hammer clips.
c. Brushes having riveted connections or hammer clips and are worn to within 1/8-inch of the metallic part.
d. Brushes having tamped connections and without hammer clips and worn to one-half or less of the original length of the brush.
e. Brushes having spring-enclosed shunts and worn to 40 percent or less of the original length of the brush exclusive of the head which fits into one end of the spring.

300-4.7.7.1.4 Where brush springs are of the positive gradient (torsion, tension, or compression) type and are adjustable, they should be adjusted as the brushes wear, in order to keep the brush pressure approximately constant. Springs of the coiled-band constant-pressure type and certain springs of the positive-gradient type are not adjustable except by changing springs.

300-4.7.7.1.5 Brush pressure should be in accordance with the manufacturer's technical manual. Pressures as low as 1-1/2 lb/in^2 of contact area may be specified for large machines and as high as 8 lb/in^2 of contact area may be specified for small machines. If technical manuals are not available, a pressure of 2 to 2-1/2 lb/in^2 on contact area is recommended for integral horsepower and integral kilowatt machines, and about twice that pressure for fractional horsepower and fractional kilowatt machines.

300-4.7.7.1.6 To measure the pressure of brushes operating in box type brush holder, insert one end of a strip of paper between the brush and commutator; use a small brush tension gage (such as the type GD-200, 200-2000 grams, 7-70 ounces, NSN 6635-01-074-9979 distributed by Jonard Industries Inc.) to exert a pull on the brush in the direction of the brush holder axis. Note the reading of the gauge when the pull is just sufficient to release the strip of paper so that it can be pulled out from between the brush and commutator without offering resistance. This reading divided by the contact area may be considered to be the unit operating pressure. Taking correction factors into consideration, the actual pressure will be a few percent lower in the case of brushes operating in the leading position and a few percent higher in the case of brushes operating in the trailing position.

300-4.7.7.1.7 All brush holders should be the same distance from the commutator, not more than 1/8-inch, nor less than 1/16-inch, unless otherwise specified by the manufacturer.

300-4.7.7.1.8 The toes of all brushes on each brush stud should line up with each other and with the edge of one commutator segment.

300-4.7.7.1.9 Brushes should be evenly spaced around the commutator. To check brush spacing, wrap a strip of paper around the commutator and mark the paper where the paper laps. Remove the paper from the commutator, cut at the lap, and fold or mark the paper into as many equal parts as there are brush studs. Replace the paper on the commutator and adjust the brush holders so that the toes of the brushes are at the creases or marks.

300-4.7.7.1.10 If brushes are staggered follow the correct method in Figure 300-4-6 to prevent grooving of the commutator. The incorrect method of staggering, shown in Figure 300-4-6, gives unsatisfactory results because the pitting effect is different under positive and negative brushes. For machines having a number of poles equal to two times an odd number, it will obviously not be possible to stagger all the brushes in accordance with the correct method. Stagger all but the odd pair of brushes in accordance with the correct method, and the odd pair in a separate track where possible or in sequence with any other pair when sufficient adjustment for a separate track does not exist. There is no need to stagger brushes when the machine has only one row of brushes (one brush holder per brush holder arm).

300-4.7.7.1.11 The brush surface in contact with the commutator or slip ring should be fully and uniformly fitted to the commutator. Brush fit (seat) can be determined by close inspection of the brush surface after a period of operation. Properly fitted brushes (100 percent seated) should have a uniform glossy surface with no distinct transition lines between any two areas of the contact surface. For magnetic minesweeping generators 100 percent seating of the commutator brushes is essential for minimizing the stray field signature of the generator. See paragraphs 300-4.7.7.3 and 300-4.7.7.4 for instructions on fitting brushes.

300-4.7.7.2 Unsatisfactory Brush Performance. The data outlined in Table 300-4-6 covers most of the problem symptoms and probable causes of unsatisfactory brush performance in typical shipboard dc motors and generators. The remedy is usually self-evident when the cause is identified and is; therefore, omitted from the outline. The numerous causes listed opposite most indications may be confusing at first glance. Usually, however, there will be more than one indication of a faulty condition. The problem of finding the right cause can be simplified by first investigating those causes which are common to all observed indications.

300-4.7.7.3 Fitting Brushes. Whenever new brushes are installed or old brushes do not fit, they should be fitted and seated. Sandpaper should be used. The use of a seating stone to seat brushes is not recommended. Never use emery cloth, crocus cloth, emery paper, or carborundum for seating brushes or polishing the collector. In addition to being conductors, the particles are very abrasive, and any particles that become imbedded in the brush face will score the collectors.

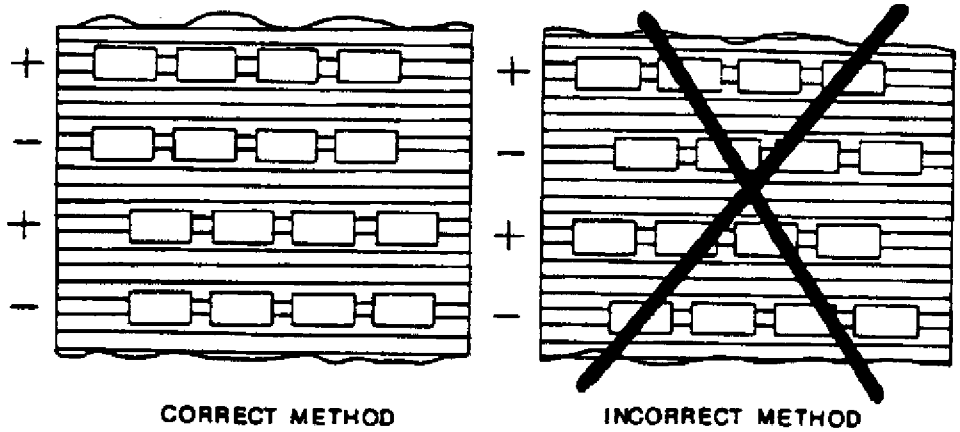


Figure 300-4-6 Staggering Brushes

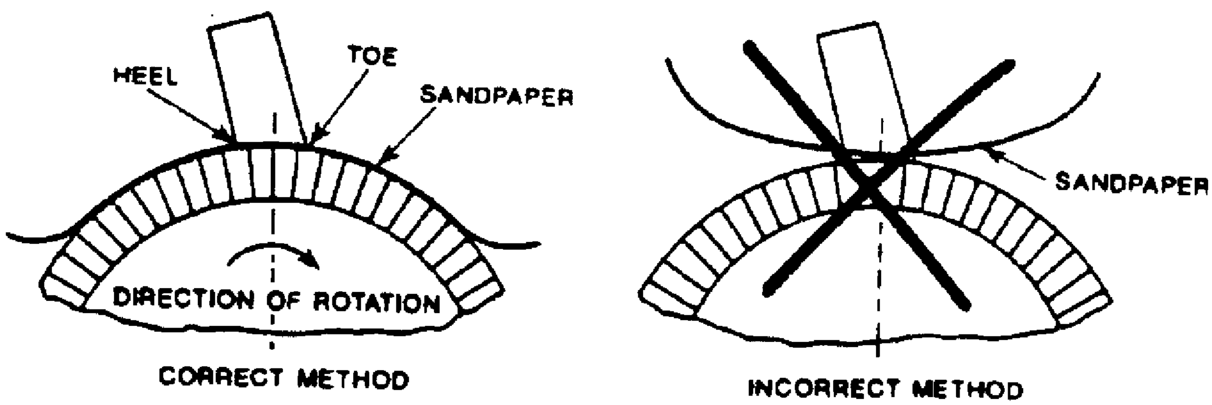


Figure 300-4-7 Sandpapering Brushes

300-4.7.7.4 Use of Sandpaper. Sandpaper should be used when fitting new brushes to the collector. After all old brushes have been removed and all collector surface or brush box remedial action has been accomplished, one of the following methods should be used to seat new brushes:

a. Preferred Seating Method. Sandpaper can be purchased on a roll and is available in sizes to fit the entire circumference and width of the collector area desired. Seating all brushes simultaneously on smaller machines and by the row on larger machines rather than singularly may be accomplished. The grade of sandpower should be medium (80 grit). Wrap the sandpaper around the collector in the direction opposite rotation and overlap. It can be held in position with cellophane or masking tape, but ensure the tape does not pass under a brush box. Install brushes to be seated. Brushes are firmly held in place be resetting the tension lever arm with the spring tab set for normal operating pressure. When desired number of brushes have been installed, manually rotate the rotor slowly in the direction of rotation. Approximately 5-6 revolutions of the rotor are required to achieve the correct contour. Lift and inspect several brushes to ensure no further seating is required. Never pull the sandpaper from under the brushes because this will round brush edges, scratch the brush surfaces and unnecessarily contaminate components with carbon dust. When seating has been completed, turn the rotor in the direction of rotation until the overlap of sandpaper is visible. Remove the tape and lift the top layer of sandpaper at the overlap. Remove the sandpaper by rotating the rotor slowly in the direction of rotation and rolling the bottom layer of sandpaper (grit side in) until all of the paper is free of the collector. This method maintains a smooth surface on the brush and reduces carbon fouling of the machine's internals. The machine should then be vacuumed and blown out with clean, dry air to remove all free carbon dust. Ensure that no adhesive residue is left on the collector surface.

b. Alternate Seating Method. When it is preferable not to rotate the rotor or adequate access cannot be gained to the brush boxes, the following alternate method may be used to seat brushes. With this method, brushes are inserted only into brush boxes readily accessible through access openings. When seating brushes, the sandpaper should be pulled in the direction from the heel to the toe of the brush with the grit side facing the brush. The brush tension should be adjusted for maximum pressure during the sanding operation, and the ends of the sandpaper should be pulled along the curvature of the collector to prevent rounding the edges of the brushes (see Figure 300-4-7). Lift the brush when returning the sandpaper for another pull. To facilitate this operation, coarse sandpaper (40 grit) may be used for the initial cutting, followed by a medium grade (80 grit) for the final cut. The brushes must be lifted when changing grades of sandpaper. After the brushes have been seated, they may be transferred to the brush boxes not readily accessible to the access opening. This technique should be repeated until all brushes are seated. When installing brushes in inaccessible brush holders ensure that the proper tension is applied to the brush. When all of the brushes have been seated, ensure tension device of brush holders used to seat brushes is returned to the proper tension. The machine should be cleaned as previously specified.

c. Slip Ring Brushes. It is usually easier to seat slip ring brushes one slip ring at a time rather than simultaneously as is typical with commutator brushes, but either technique is acceptable. By using the preferred method of brush seating, little possibility exists that unsatisfactory brush contours will be developed. Because slip ring diameters are generally smaller than commutator diameters, particular care must be taken when seating brushes by the alternate method to prevent curved brush edges and to ensure the brush contour conforms to the slip ring.

Table 300-4-6 BRUSH PROBLEMS AND PROBABLE CAUSES

Symptom	Probable Cause
AT BRUSHES:	
Rapid brush wear	Humidity too low Incorrect spring pressure Wrong brush grade Brushes too tight in holders Brushes too loose in holders Brushes holders loose at mounting Coefficient of friction too high Presence of vapors from silicone base material Loose or unstable foundations Environmental vibration
Brush chipping or breaking	Brushes too tight in holders Brushes too loose in holders Brush holders loose at mounting Commutator loose Environmental vibration (See Chattering noisy brushes)
Chattering or noisy brushes	Poor preparation of commutator surface High mica Brushes in wrong position Incorrect brush angle Incorrect spring pressure

Table 300-4-6 BRUSH PROBLEMS AND PROBABLE CAUSES - Continued

Symptom	Probable Cause
	Brushes too loose in holders Brush holders loose at mounting or too much clearance between brush holder and commutator Commutator loose Underload or low average current density in brushes Oil on commutator or oil mist in air Humidity too low Environmental vibration Coefficient of friction too high Too much abrasive action in brushes Lack of film forming properties in brush
Brush sparking	Poor preparation of commutator surface High mica Feather-edge mica Brushes in wrong position Unequal brush spacing Poor alignment of brush holders Series field improperly adjusted Brushes too tight in holders Brushes too loose in holders
Brush sparking (Continued)	Brushes holders loose at mounting Commutator loose Loose pole pieces or pole Loose or worn sleeve bearings Unequal air gaps Internally excited vibration Open or high resistance connection at commutator Loose soldered connection between commutator risers and armature coils Poor connection at shunt terminal Short circuit in field of armature winding Ground field or armature winding Reversed polarity on main pole or commutating pole Commutating zone too narrow Commutating zone too wide Brushes too thin Brushes too thick Underload or low voltage current density in brushes Reversing operation of noncommutating pole Dynamic braking Contaminated atmosphere Oil on commutator or oil mist in air Humidity too low Loose or unstable foundation Environmental vibration

Table 300-4-6 BRUSH PROBLEMS AND PROBABLE CAUSES - Continued

Symptom	Probable Cause
	Contact drop of brushes too low Lack of film forming properties in brush Lack of polishing action in brush
Etched or burned bands on brush face	Brushes in wrong position Commutating poles improperly adjusted Bar edges not chamfered after undercutting Commutator loose
Dull or dirty surface	Need for periodic cleaning Contaminated atmosphere Lack of polishing action in brush
Eccentric surface	Poor preparation of commutator surface Loose or worn sleeve bearings Environmental vibration
High commutator bar Low commutator bar	Commutator loose High mica Open or high resistance connection at commutator
Streaking of threading surface	Poor preparation of commutator surface High mica Underload or low average current density in brushes Contaminated atmosphere Oil on commutator or oil mist in air Abrasive dust in air Humidity too high Lack of film forming properties in brush Brushes too abrasive (See Glowing at brush face)
Bar etching or burning	Poor preparation of commutator surface High mica Need for periodic cleaning Brushes in wrong position Incorrect spring pressure Commutating poles improperly adjusted Brushes too tight in holders Commutating zone too narrow Commutating zone too wide Brushes too thick High bar-to-bar voltage Overload Rapid change of load External short circuit or very heavy load surge
Bar marking at pole pitch	Open or high resistance connection at commutator Commutating zone too narrow Commutating zone too wide Brushes too thin Brushes too thick

Table 300-4-6 BRUSH PROBLEMS AND PROBABLE CAUSES - Continued

Symptom	Probable Cause
Copper in brush face	High mica Feather-edge mica Underload or low average current density in brushes Oil on commutator or oil mist in air Abrasive dust in air Humidity too high Humidity too low Lack of film forming properties in brush Brushes too abrasive
Glowing at brush face	Brushes in wrong position Commutating poles improperly adjusted Overload Rapid change of load Dynamic braking Oil on commutator or oil mist in air Abrasive dust in air Contact drop in brushes too low Lack of current carrying capacity Lack of current carrying capacity (See Copper in brush face)
Pitting of brush face	(See Glowing at brush face and Copper in brush face)
Flashover at brushes	Need for periodic cleaning Incorrect spring pressure Brushes too tight in holders High bar-to-bar voltage Overload Rapid change of load External short circuit or very heavy load surge
AT COMMUTATOR SURFACE:	
Rough or uneven surface	Poor preparation of commutator surface High mica Feather-edged mica Insufficient cross-connection of armature coils
Bar markings at slot pitch spacing	Brushes in wrong position Commutating poles improperly adjusted Commutating zone too narrow Contact drop of brushes too low Lack of polishing action in brush
Flat spot	Poor preparation of commutator surface Need for periodic cleaning Incorrect spring pressure Brushes too tight in holders Loose or worn sleeve bearings Torsional vibration Open or high resistance connection at commutator High bar-to-bar voltage

Table 300-4-6 BRUSH PROBLEMS AND PROBABLE CAUSES - Continued

Symptom	Probable Cause
	Overload Rapid change of load Dynamic braking External short circuit or very heavy load surge
Blackening of all bars or blackening on groups of bars at regular intervals	Brushes in wrong position Incorrect spring pressure Commutating pole improperly adjusted
Blackening on a single bar	Open or high resistance connection at commutator
Blackening at irregular intervals	Poor preparation of commutator surface Loose or worn sleeve bearings Internally excited vibration
Carbonized mica	Need for periodic cleaning Oil on commutator or oil mist in air
Discoloration of surface	Contaminated atmosphere Oil on commutator or oil mist in air Lack of polishing action in brush (See Heating in commutator)
Raw copper surface	Underload or low average current density in brushes Abrasive dust in air Humidity too low Lack of film forming properties in brush Brushes too abrasive (See Copper in brush face)
Rapid commutator wear with blackened surface	High mica Feather-edge mica Incorrect spring pressure Brushes too tight in holders (See Sparking)
Rapid commutator wear with bright surface	Underload or low average current density Abrasive dust in air Humidity too low Brushes too abrasive
AT BRUSH STUDS:	
Arching between brush studs	Need for periodic cleaning Dynamic braking Oil in commutator or oil mist in air
Heating in windings	General overheating of the machining not confined to commutator and brushes Clogged ventilating ducts Brushes in wrong position Unequal brush spacing Series field improperly adjusted Loose pole pieces or pole face shoes

Table 300-4-6 BRUSH PROBLEMS AND PROBABLE CAUSES - Continued

Symptom	Probable Cause
	Loose or worn sleeve bearings Unequal air gaps Unequal pole spacing Open or high resistance connection at commutator Short circuit in field or armature winding Ground in field or armature winding Reversed polarity on main pole or commutating pole Magnetic saturation of commutating poles Insufficient cross connection of armature coils Overload Dynamic braking Abrasive dust in air
Heating in commutator	Brushes in wrong position Unequal brush spacing Poor alignment of brush holders Incorrect brush angle Incorrect spring pressure Unequal air gaps Brushes too thick High ratio of brush contact to commutator surface area Overload Underload or low average current density in brushes Dynamic braking Humidity too low Contact drop of brushes too high Contact drop of brushes too low Coefficient of friction too high Lack of film forming properties in brush
Heating at brushes	Brushes in wrong position Incorrect brush angle Incorrect spring pressure Commutating poles improperly adjusted Poor connection at shunt terminal Overload Dynamic braking Contact drop of brushes too low Coefficient of friction too high Lack of film forming properties in brush Brushes too abrasive Lack of current carrying capacity

300-4.7.7.5 Setting Brushes on Neutral Position. The no-load neutral point on a commutator is the point at which minimum voltage is induced between adjacent commutator bars when the machine is running without load and with only the main pole field windings excited.

300-4.7.7.5.1 The neutral point is usually the best running position of the brushes on commutating pole machines. The manufacturer usually sets the brush studs in the proper position and marks the correct brush setting by a chisel mark or an arrow on a stationary part of the machine. It is normally not necessary to shift from the position marked by the manufacturer, but because of bearing wear or other causes it sometimes happens that commutation can be improved by shifting the brushes slightly from the marked position. Brushes of commutating pole generators are often shifted slightly forward ahead of the mechanical neutral in the direction of rotation, to insure a drooping voltage characteristic. The correct neutral position can be found by the use of:

a. The mechanical method

b. The reversed rotation method

c. The kick method.

300-4.7.7.5.2 The mechanical method is an approximate method. Turn the armature until the two coil sides of the same armature coil are equidistant from the center line of one main field pole. The commutator bars to which the coil is connected give the position of the mechanical neutral.

300-4.7.7.5.3 The reversed rotation method can only be used where it is practical to run the machine in either direction of rotation and apply rated load in both directions of rotation. For motors, run the motor in the normal direction under full load at line voltage until the field current becomes constant. Accurately measure the speed with a tachometer. Reverse the direction of rotation, apply full load, and measure the speed. Shift the brushes until the speed of rotation is the same in both directions. For generators which can be operated in both directions, run the generators at the same field strength and the same speed in both directions of rotation, and shift the brushes until the full load terminal voltage is the same for both directions of rotation.

300-4.7.7.5.4 The kick method may be used for initial settings and when conditions are such as to warrant the risks involved. Sufficient resistance must be connected in series with the field coils to reduce the field current to approximately 10 percent of normal value. The rapid interruption of full field current induces voltages which are dangerous to personnel and which may cause breakdown of insulation.

300-4.7.7.5.5 With a lead pencil or other means that will not damage the surface, mark A on a commutator bar under one set of brushes. Mark B on another bar one pole pitch away from the center of the bar marked A. A pole pitch is the angular distance from the center of one main pole to the center of the next main pole. Raise all brushes. Connect bars A and B to a low range voltmeter having two or three scales (for example, 0-0.5, 0-1.5, 0-15 volts). Use leads with pointed prongs to connect the bars. Separately excite the shunt field winding from a dc source connected to the winding in series with a high resistance and a quick-break switch. Start with the minimum obtainable value of field current and the high range scale of the voltmeter.

300-4.7.7.5.6 Close the knife switch, wait for the momentary deflection to disappear, open the knife switch, and note the momentary deflection or kick of the voltmeter. If insufficient deflection is observed on the lowest range scale of the voltmeter to take a reading, decrease the resistance connected in series with the shunt field winding and repeat the procedure until an adequate deflection is obtained on the voltmeter when the switch is opened. Retain this setting of the resistor for remainder of the test. Turn the armature slightly until the position is found at which the minimum kick is produced when the field current is broken. Bars A and B will then be on neutral. If one pole pitch from the center of bar A does not fall on a bar, but on the mica between two bars, mark the bars next to the mica, C and D. Then measure the kick when bar A and bar C are connected to the voltmeter, and again when A and D are connected to the voltmeter. Adjust the position of the armature until these two deflections are equal and opposite. The centerline of bar A and the mica between bars C and D will then be on neutral.

300-4.7.8 COMMUTATOR CARE. Within about two weeks of use, the commutator of a properly operating machine will develop a uniform, glazed, dark brown polish where the brushes ride on it. A nonuniform color or surface, or a bluish color indicates improper commutation conditions. If the commutator retains a smooth, uniform finish of the proper color and shows no evidence of poor commutation, it may be cleaned as described in paragraph 300-4.7.8.1 and should not be sandpapered, ground, or turned. If, however, the commutator is blackened and if dirt cannot be removed with a cloth, it may be removed with a flexible abrasive stone. If a generator is to be secured for one week or longer, protect the commutator from damage to the surface from electrolytic action in a manner similar to that for collector rings (paragraph 300-4.7.9.3).

300-4.7.8.1 Commutator Cleaning. One of the most effective ways of cleaning a commutator is to apply a canvas wiper while the machine is running. A canvas wiper (Figure 300-4-8) can be made by wrapping several layers of hard woven untreated canvas over the end of a strong, pliable, wood strip and securing the canvas with rivets. The strip should be long enough so that the user can hold it securely in both hands, about 1/4 to 3/8 inch thick, and of a width appropriate to the size of the machines on which it will be used. Linen tape should be wrapped around the canvas wiper over the rivets to prevent all possibility of their coming in contact with the commutator.

300-4.7.8.1.1 The canvas wiper is applied to the commutator in either of the ways illustrated in Figure 300-4-8. When the outer layer of canvas becomes worn or dirty, it is cut off to expose the next layer. The canvas wiper should be used frequently to be most effective. Under severe conditions it will be desirable to use the canvas wiper every few hours, or at least once a watch, and even when the accumulation of deposit on the commutator is slow, it is advisable to use the canvas wiper at least once a day. When using the wiper, care should be exercised to keep from fouling any moving parts.

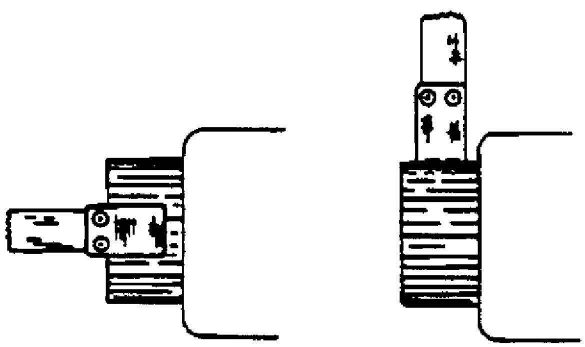


Figure 300-4-8 Commutator Cleaning

300-4.7.8.1.2 When the machine is secured, use a toothbrush to clean out the commutator slots, and wipe the commutator and adjacent parts with clean canvas or cheesecloth. Take care not to leave threads lodged between the commutator bars or on the brushes. Do not use cotton waste or any cloth which leaves lint. Keep the commutator neck and the spaces between commutator bars clean.

300-4.7.8.1.3 Do not use inhibited methyl chloroform or trichlorotrifluoroethane for routine cleaning of commutators since these liquids dissolve the desired dark brown glaze on the commutator surface. However, if dirt cannot be removed by normal means, a flexible abrasive stone such as MIL-S-17346, 5/8 x 5 inches (FSN 5345-00-678-1893) may be used. Care must be exercised not to get residue trapped under or between the brushes.

300-4.7.8.1.4 Never use a lubricant on the commutator, either during or after the period when the canvas wiper is being used to clean and polish the commutator. Oil and lubricants tend to develop a high resistance film on the commutator, dissolve the binder out of the mica insulation, and cause carbonization resulting in eventual breakdown of the insulation between commutator bars.

300-4.7.8.1.5 In addition to wiping, clean the commutator periodically with a vacuum cleaner, or blow out with clean, dry air in accordance with paragraph 300-4.5.2. This should be done in every case after the commutator has been ground, or turned, after brushes are sandpapered to fit, and after solvents have come into contact with the commutator.

300-4.7.8.1.6 When sandpapering the brushes, or when performing any operation which produces dust, grit, or shavings, great care must be taken to protect all windings and vent spaces from foreign particles. Stationary coils should be protected by a guard and the armature fitted with a canvas head securely bound on the commutator and armature surfaces. Vent spaces under the commutator should be protected by stuffing them with clean rags. Be sure to remove the rags when all work is completed. Mask open spaces between risers to prevent foreign particles from entering between the risers. Clean the commutator with a vacuum cleaner or compressed air and wipe with lintless cloth.

300-4.7.8.2 Sandpapering the Commutator. Do not sandpaper a commutator. If poor operation indicates resurfacing is necessary, first try cleaning the commutator using a canvas wiper as outlined in paragraph 300-4.7.8.1.1 or strip the film with a flexible abrasive stone. If a decision is made that the commutator should be resurfaced, the following checks should be made prior to the resurfacing, to prevent the unsatisfactory condition from recurring after resurfacing.

a. Be sure that proper brushes are installed.

b. Never mix two grades or manufacturer’s types of brushes on a single commutator, even if supplied under the same stock number.

c. All brush holder springs should be adjusted to the proper tension using a spring scale.

d. Brush holders shall be set at proper angle.

e. Brush holders should be at specified distance from commutator (adjust where adjustment means are provided).

f. All brush holder arms shall be aligned parallel to commutator bars.

g. Brush holder arms shall be spaced exactly equidistant around the commutator.

h. Brush holders with worn parts should be rebuilt or replaced.

i. Brushes shall move freely in boxes.

j. Frayed pigtails and worn hammer plates indicate brush chatter which is usually caused by wrong spring pressure, wrong brushes, worn brush holders, long periods at light load, or a commutator out of round. However, commutators out of round very seldom are the cause of worn hammer plates or frayed pigtails.

k. Brushes are set on neutral.

l. Mica is undercut to below commutator surface.

m. Commutator bar edges have been chamfered.

300-4.7.8.2.1 Sandpapering should not be used to resurface a commutator. Because of its flexibility (even when used with a block curved to fit the commutator), it has a tendency to round edges of the bars; however, spot resurfacing with sandpaper without machine rotation is acceptable.

300-4.7.8.2.2 Do not use emery paper, emery cloth, emery stone, or crocus cloth on a commutator. Emery is extremely abrasive and is an electrical conductor. When emery is used on a commutator, particles become embedded in the brushes and between the commutator bars, injuring the commutator surface and causing short circuits.

300-4.7.8.3 Truing up the Commutator. A commutator should be trued in place only if its condition has become so bad it cannot wait until the next ship overhaul for reconditioning. Large commutators in the 125-850 r/min range, as fitted on most electric propulsion motors and generators, usually operate satisfactorily with runouts up to 3 mils (0.003 inch). Under any conditions, do not attempt to true a commutator in place unless there is sparking, excessive brush wear, or brush movement sufficient to fray the brush pigtails and wear the hammerplates. Do not confuse brush chatter (as discussed in paragraph 300-4.7.8.2j) with brush movement by runout. Sandpapering will not correct flat spots, grooves, eccentricity, or out of round. Measures which will correct some or all of these conditions are:

a. Hand stoning (paragraph 300-4.7.8.4)

b. Grinding with a rigidly supported stationary or revolving stone (paragraph 300-4.7.8.5)

c. Turning (paragraph 300-4.7.8.6).

300-4.7.8.3.1 There are a number of grades of commutator stone from very coarse to very fine that can be used for hand stoning or grinding with a rigidly supported stone. Use the finest stone that will do the job in reasonable time. Do not use excessively coarse stones as they tend to produce scratches which are hard to remove.

300-4.7.8.3.2 After the truing up has been completed, whether by stoning, grinding, or turning, finish with a fine grade of stone, undercut the mica, chamfer the commutator bars, clean the commutator and brush holders, and wipe off the brushes with a clean, dry, lint free cloth then polish with a polishing stone to remove any burrs or rough edges.

CAUTION

Hand stoning should be performed only by experienced personnel when stoning by machine cannot be accomplished.

300-4.7.8.4 Hand Stoning. Hand stoning is not recommended for resurfacing. Hand stoning cannot effectively eliminate collector irregularities and may result in personnel injury.

300-4.7.8.4.1 The stone should be formed or worn to the curvature of the commutator and should have a surface substantially larger than the largest flat spot to be removed. The stone is held in the hand and moved very slowly back and forth parallel to the axis of the commutator. Do not press too hard on the stone; just enough to keep it cutting. Undue haste or crowding of the stone will result in a rough surface, and sometimes a noncylindrical shape of the commutator. Exercise care to avoid electric shock, or jamming the stone between fixed and moving parts of the machine. Suitable stones for hand stoning are available through the navy supply system, NSN 5345-00-685-4349 (coarse), NSN 5345-00-685-4350 (fine), and NSN 5345-00-685-4351 (medium).

300-4.7.8.5 Fixed Stoning. Fixed stoning should be used in cases of eccentricity, high bars, or out of round conditions. Three methods of stoning are employed:

a. The fixed stone may be used with the rotor installed in the set and the rotor being turned, usually with an air driven motor. The rig which holds the stones is attached to the set and provides the stability needed to attain a true concentric surface. Stoning in place is normally preferred because the collector is turned on its own bearings and a much truer surface is acquired. Figure 300-4-9 A and B illustrates a typical stoning rig. Slight modifications have to be made to the unit as shown for use aboard ship (primarily a mounting plate to attach rig to the set). Figure 300-4-9B shows the arrangement of the rig with relationship to the centerline of the collector. The purpose of this mounting method is to prevent gouging damage if the stones fracture in use; the stone will fall away rather than jam. If rotation were in the opposite direction, it would be mounted below the centerline. Figure 300-4-9C shows that vacuum attachments may be used to reduce the accumulation of metal fines in the machine during the stoning process. Ideal Corporation, a major supplier of cutting stones available in the supply system, gives a nominal tangential velocity of 750 feet per minute for these stones. Rotors will oil lubricated bearings should be turned at or near rated speed to ensure proper lubrication of the bearings. In these cases, rate of feed should be reduced to avoid breaking the stone. Speeds for machines with known collector diameters can be readily calculated by the following formula:

$$RPM = \frac{2865}{Diameter}$$

Figure a.

RPM = Turning speed for stoning rig.

Diameter = Collector diameter in inches. The rig used to traverse the stone across the collector surface should be mounted where the brush holder bracket is closest to an access cover. This bracket can usually be removed and the stoning rig mounted in the existing threaded holes. To stone collectors, the rig should be mounted where it provides best access through the bearing bracket to the collector surface.

b. The armature may be removed from the machine and mounted in a lathe where it is rotated. The commutator stone is mounted in the tool post and fed to the commutator.

c. The armature may be removed from the machine and mounted in a lathe where it is rotated. A rotating precision grinder is mounted in the tool post and the grinder wheel fed to the commutator. A medium abrasive wheel, such as type 37C60M4E, MIL-STD-165, is recommended.

   1 In the case of some of the larger open and dripproof machines, a commutator resurfacer conforming to MIL-R-3907 is mounted on the frame of the machine and holds a commutator stone against the commutator as the armature is rotated.

   2 The armature may be removed from the machine and mounted in a lathe where it is rotated. The commutator stone is mounted in the tool post and fed to the commutator.

   3 The armature may be removed from the machine and mounted in a lathe where it is rotated. A rotating precision grinder is mounted in the tool post and the grinder wheel fed to the commutator. A medium grade aluminum oxide abrasive wheel is recommended.

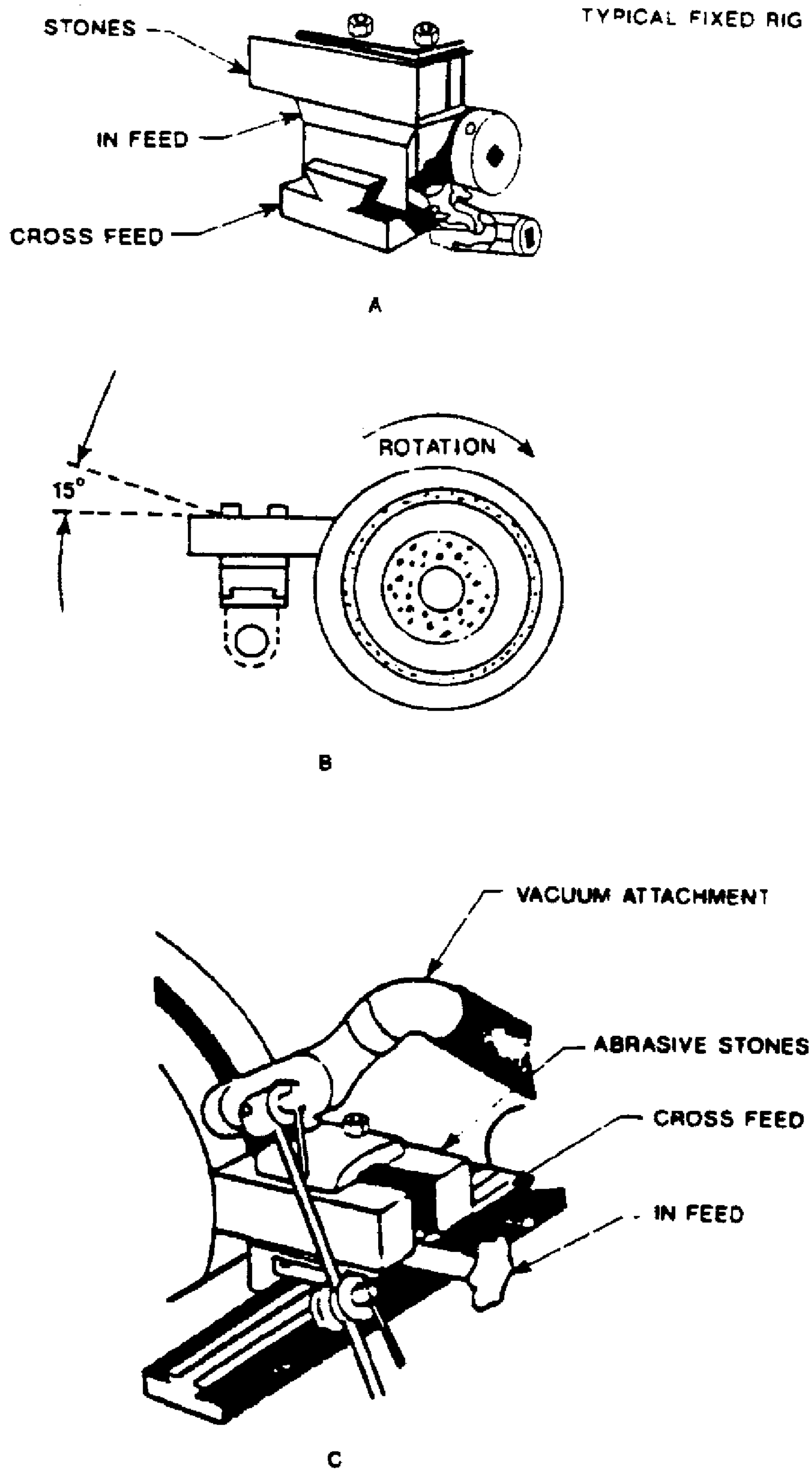


Figure 300-4-9 Cutting Stones in Fixed Rigs

300-4.7.8.5.1 Regardless of the method, it is essential that the cut be strictly parallel with the axis of the machine. Otherwise, a taper on the commutator will result.

300-4.7.8.5.2 Do not disturb the commutator clamping bolts unless there is direct evidence that the bars are loose (one or more high bars). Then use a calibrated torque wrench and tighten only to the values as specified by the manufacturer. For propulsion motors and generators, these values are available from NAVSEA. Make all other needed repairs such as balancing, rebrazing armature connections, and repairing insulation faults prior to truing the commutator.

300-4.7.8.5.3 When practical, the armature should be removed from the machine and placed in a lathe for grinding. If this is impractical, the commutator can be ground in the machine provided the windings can be adequately protected from grit and suitable supports can be found for the stone, and there is not too much vibration. The use of graphite rather than oil to lubricate the moving parts of the grinder is suggested. Oil catches the gritty materials from the grinding operation, and hence cause undue wear of equipment. Rig the grinder so that the top of the stone is below the axis of maximum commutator diameter. If stone slippage or breakage occurs, the pieces will swing away from (and not into) the commutator.

300-4.7.8.5.4 When grinding the commutator in the machine, the armature can be rotated by an external prime mover or, in the case of a motor, by supplying power through just enough brushes to take care of the load. It is preferable to discard these brushes after grinding. Old brushes may be used for this purpose. Whenever grinding is done in a motor, take care to avoid electric shock and fouling of any of the equipment used with the moving parts of the motor.

300-4.7.8.5.5 Commutator surfacing stones with tool post handles are carried in stock in various sizes and grades (such as NSN 5345-01-020-9784 (fine), NSN 5345-01-020-9783 (medium), and NSN 5345-01-020-9782 (coarse)). When used, the stone should be rigidly clamped in a holder and substantially supported to keep the stone from chattering or digging into the commutator. The supports must provide for axial motion of the stone. Heavy cuts must be avoided since the stone wears away as it is moved back and forth. If a heavy cut were taken, the commutator would not have the same diameter at both ends.

300-4.7.8.5.6 A medium soft grinding wheel should be used so that the face will not fill up with copper too rapidly. Use a light cut even if the commutator is badly distorted and a large number of light cuts are needed. If a heavy cut is used, the commutator may be ground to a noncylindrical shape and initial eccentricity may be retained because of the elasticity of the support. The speed of the wheel should be that recommended by the manufacturer. The speed of the commutator should be moderate (one-half to three-fourths normal speed) until most of the eccentricity has been removed. After this, the commutator should be rotated at approximately normal speed.

300-4.7.8.6 Turning the Commutator. When armatures are removed to the shop for overhaul, the armature should be placed in a lathe for truing the commutator. Before truing, make sure the shaft is straight and is in otherwise good condition. Cut only enough material to true. Small pits, burn spots between bars, or other mechanic imperfections in the bars do not have to be removed unless they would interfere with the free sliding of the brushes. If it is essential to true a commutator in place, follow the instructions of paragraphs 300-4.7.8.5 through 300-4.7.8.5.6.

300-4.7.8.6.1 The armature should be supported in a lathe and a diamond point tool should be used. This should be rounded sufficiently so that the cuts will overlap and not leave a rough thread on the commutator. The proper cutting speed is above 100 feet per minute and the feed should be about 0.010 inch per revolution. The depth of cut should be not more than 0.010 inch. The reasons for a light cut are the same as for grinding. In addition, when taking a heavy cut, a turning tool tends to twist the commutator bars and cut deeper at one end than at the other.

300-4.7.8.6.2 After turning the commutator, it should be finished with a stone.

300-4.7.8.6.3 If balancing equipment is available, the entire rotating assembly should be balanced before it is reinstalled in the machine.

300-4.7.8.7 Restoring the Commutator Film. After the oxide film has been removed from the commutator surface by sandpapering, stoning, grinding, turning, or in-place cleaning by the suction method of paragraph 300-4.5.3, it is necessary to restore the film before the machine is operated at or near full load.

300-4.7.8.7.1 Before passing any current through the commutator, the surface should be mechanically smooth and any sharp edges or slivers on the bar edges should be removed by a slotting file or a slot scraper. If there are noticeable scratches or roughness, the commutator should be burnished by a very fine commercial burnishing stone, as described in MIL-S-17346. After burnishing, carefully brush any debris from between the commutator bars. Any commutator which is shop overhauled should have the commutator surface smoothed, bar edges chamfered, and be cleaned between the bars before being reassembled in the motor or generator.

300-4.7.8.7.2 Any commutator which has been resurfaced should undergo a seasoning process to restore its oxide film before being operated at or near full load. Start with 25 percent load and operate for 2 hours. Then increase load by 10 percent every hour until full load is reached. Operate machine at full load for 4 hours. It is critical that the machine is operating on full load in the minimum time. Run at 25 percent load for 2 hours and then increase load by 15 percent every hour until full load is reached. Operate machine at full load for 2 hours. This shorter seasoning period is not recommended unless the machine is urgently needed.

300-4.7.8.8 Commutator Mica. High mica or featheredge mica may cause sparking, a rough or uneven commutator surface, streaking or threading, or numerous other difficulties. Rough or uneven commutator surfaces may also be caused by failure to chamfer the commutator segments after undercutting.

300-4.7.8.8.1 Many tools are now available for undercutting, chamfering, and smoothing slot edges. Rotary cutter, motor-driven undercutters represent one class of satisfactory tool. They are available in three types: portable with an integral motor, portable with a separator motor, and the bench type. The first two can be used while the armature is installed in the motor or generator; the armature shall be removed for use with the third type. The rotary cutters are either U- or V-shaped. U-slots will give long wear and are best suited to slow speed machines or machines which operate in a clean atmosphere and require little maintenance. V-slots, which are more quiet than U-slots, are better where dirt and dust are present. The proper thickness for a U-shaped cutter is equal to the thickness of the mica plus or minus 0.001 inch. In general, it is best not to cut U-shaped slots deeper than 1/32 or at most 3/64 inch. V-shaped slots are cut to a depth which will remove some copper at the top.

300-4.7.8.8.2 After undercutting with a U-cutter, always chamfer (bevel) the commutator bar edges 1/64 to 1/32 inches with a slotting file (NSN 5110-00-289-0531) or a slot scraper (NSN 5110-00-245-9542). Chamfering is normally not needed after undercutting with a V-shaped cutter.

300-4.7.8.8.3 Undercutting should be followed by hand stoning (paragraphs 300-4.7.8.4 and 300-4.7.8.4.1) with a class F or class EF commutator dressing stone.

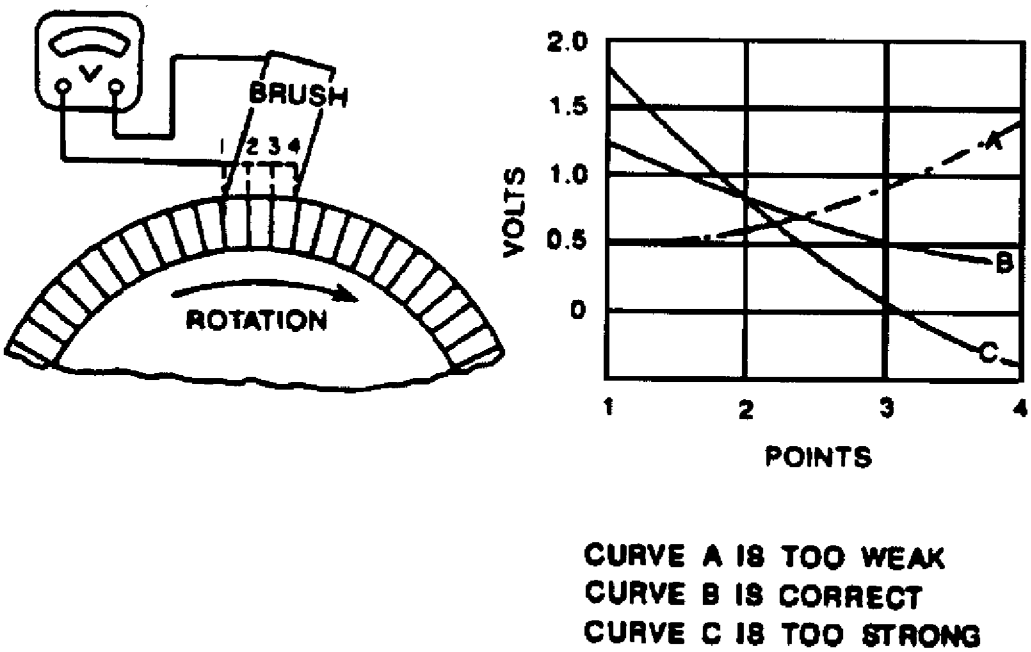


Figure 300-4-10 Checking Commutator Pole Strength

300-4.7.8.8.4 Small commutators may be undercut with a bench type undercutter or with a slotting file. A magnifying glass may be needed to check the thoroughness of the work.

300-4.7.8.8.5 If the mica becomes carbonized and loses its insulating properties, the cause is usually foreign matter, particularly oil. Scrape out the defective mica and fill the space with sodium silicate (water glass) or other suitable insulating cement.

300-4.7.8.9 Commutating Pole Strength. Commutation is affected not only by commutator and brushes, but also by commutating pole strength. The best adjustment for commutating pole strength is made at the manufacturer's plant and usually needs no change. If, however, there is good reason to suspect that incorrect commutating pole strength is responsible for unsatisfactory commutation, a check can be made as follows:

1. Make sure that the brushes are set on neutral (paragraphs 300-4.7.7.5 through 300-4.7.7.5.6).
2. With a low-reading voltmeter (range of about 3 volts), measure the voltage between the fixed point on the brush and four points spaced at equal intervals along the brush span (see Figure 300-4-10). Use a carbon prod held in insulating material to make contact with the commutator. The machine should be running at normal load and voltage. Measurements should be made from position 1 to 4 in the direction of rotation. A curve similar to curve B of Figure 300-4-10 indicates correct commutating pole strength. Curve A indicates that the commutating pole is too weak; curve C, that it is too strong. The same curves apply to both generators and motors.

300-4.7.8.9.1 The changes necessary to adjust incorrect commutating pole strength will normally be beyond the capacity of ship's force. Such changes would usually be made at a repair activity.

300-4.7.9 COLLECTOR RINGS AND BRUSHES ON AC GENERATORS. These items on ac generators should be given the same careful attention as the commutator and brushes of dc generators. To obtain and maintain good, polished surfaces:

1. Inspect the brushes regularly to see that they move freely up and down in their holders.
2. Keep the rigging free from dust, oil, salt, lint, metal particles, and dirt.
3. Brushes need no lubrication and the rings should be kept free from coating and scaling of any kind by cleaning periodically.
4. Inspect the working surfaces of the brushes occasionally and keep the full surface bearing on the rings. To prevent the formation of brush slivers, make sure that the brushes do not extend beyond the edges of the rings.

300-4.7.9.1 Scoring. Scoring of collector rings is usually due to hard particles which become embedded in the brush contact surfaces, or to incorrect grade of brush. This should be corrected by resanding and refitting the brushes, or by changing the grade of brush.

300-4.7.9.2 Flat Spots or Pitting. Flat spots or pitting may develop on collector rings from many causes. Black spots sometimes appear on collector rings. In themselves, they are not serious, but if they are not immediately removed (at the first securing of the generator) by rubbing lightly with fine sandpaper, pitting and flat spots will result, necessitating grinding of the rings.

300-4.7.9.3 Electrolytic Action. If a generator is allowed to stand secured in moist salt air, an electrolytic action may take place between the brushes and rings causing a rough imprint of the brushes on the rings. With the generator in operation, the brushes will jump at the passing of each of these rough spots, forming a small arc, thus causing flat spots due to pitting. To prevent such action it is good practice, when securing the generator for week or longer, lift the brushes off the rings and place some insulating material such as Nomex between the brush and the commutator. Be sure to remove the insulating material before energizing the equipment. As an alternative, remove the brushes entirely

300-4.7.9.3.1 If a generator is allowed to stand secured in ordinary moisture or acid fumes, the area of the collector rings not covered by the brushes may be corroded. The best way to prevent corrosion, electrolytic action, pitting, and flat spots is to run the generator for a short time every day.

300-4.7.9.3.2 A slight unbalance in the rotor may cause the brushes to jump at each revolution. The resulting small arc will leave an imprint of each brush on the ring to induce pitting and flat spots. Flat spots due to rotor unbalance always occur at the same place on the rings relative to the rotor. Those due to any of the other causes occur at any point where the machine happens to stop when secured.

300-4.7.9.3.3 Flat spots due solely to brush friction, may develop where the rings are not of uniform hardness. The only cure for this is to replace the rings.

300-4.7.9.3.4 Flat spots or an imprint of brushes on the rings may be caused by sticking or cocking of the brush in the holder, instability of the brush holder, or light brush pressure.

300-4.7.9.3.5 Pitting sometimes develops because of the electrolytic action on the surface of the rings caused by current flow. Sometimes it will be evident in one ring only. This pitting is general over the whole ring area and does not cause localized flat spots. When this condition is observed, reverse the polarity of the rings. Keep the rings under frequent regular observation and, if pitting and discoloration tend to become unequal in the other direction, continue to reverse the polarity at intervals as found necessary to maintain equality in the surface condition. Leads to the collector brushes or at the switchboard should be made long enough to permit this reversal of polarity. Reversal of the polarity of the rings will in no way affect the phase rotation of the generator.

300-4.7.9.3.6 Pitting and burning will result if the field current is allowed to flow through the collector rings while the machine is secured. In severe cases, pitting must be removed by stoning or turning. Final polish can be obtained by use of a fine grade stone. In light cases the rings may be dressed with sandpaper, followed by polishing with crocus cloth.

300-4.7.9.4 Additional Information. For additional information on brushes, slip rings and commutators, see S6269-AQ-HBK-010, **Slip Ring Maintenance Handbook** and S9310-AC-HBK-010, **Commutator/Slip Ring Maintenance Handbook** .

300-4.7.10 GROUNDS. A ground on a machine or circuit that is not intentionally grounded is a zero or low-resistance path which is caused by a breakdown in insulation and which extends from ground to a winding or some other conductor in the machine or circuit.

300-4.7.10.1 Single Ground. A single ground in any of the windings of a machine or which is connected to an ungrounded system will cause no particular harm to the machine but will result in a short circuit if a second ground occurs. For this reason, machines should be periodically tested for grounds.

300-4.7.10.2 Testing for Grounds. When testing for grounds (except when a permanently installed ground detector voltmeter is used) make sure that the machine is disconnected from its normal power supply and will not be inadvertently started while the test is being made. The following methods can be used to test for grounds.

a. Use an insulation-resistance-measuring instrument to measure the insulation resistance between the suspected winding and the shaft or frame of the machine. This is the preferred method as it furnishes definite information with respect to insulation resistance. See paragraphs 300-4.7.19 through 300-4.7.19.6 for recommended frequency of insulation resistance measurements and paragraphs 300-3.4.8 through 300-3.4.11.1 for information relative to the magnitude of insulation resistance to be expected.

b. When an insulation-resistance-measuring instrument is not available, a voltmeter and a dc source (about 120 volts) can be used to measure insulation resistance (see paragraphs through 300-3.2.4 through 300-3.2.4.2).

c. Another method is to connect one terminal of a magneto ringer to ground and the other terminal to the winding to be tested. If there is a ground, the magneto will ring through.

d. A ground detector voltmeter provides another method of testing for grounds. See paragraphs 300-3.2.6.3 through 300-3.2.6.3.3 for instruction on its use.

300-4.7.10.3 Grounds in ac Stator Windings. If any of the foregoing tests indicate there is a ground in the stator of an ac generator or motor, it is sometimes possible to locate the ground by smoking it out. Connect one side of a lighting circuit to the frame of the machine through a 30-ampere fuse. Connect the other side of the circuit to the stator through a 5-ohm resistance having a current-carrying capacity of about 25 amperes. This may permit sufficient current flow through the ground to cause the grounded coil to smoke and thus reveal its location without the necessity of opening up the phases, circuits, and coils. If the ground has very low resistance, or too high resistance, this method of locating the ground will not be suitable and it will be necessary to test each coil separately, as follows:

1. Open both ends of each phase and test each to locate the grounded phase.
2. Open each circuit in the grounded phase and test to locate the grounded circuit.
3. Open the ends of each coil in the grounded circuit and test each coil individually until the grounded coil is found.

300-4.7.10.4 Grounds in Field Windings. In testing for grounds in the field circuit, the various field circuits of a dc machine (shunt, series, and interpole) should be disconnected from each other. If a ground in any of one field circuit is indicated, the connections between all coils in that circuit must be opened and each coil tested separately to locate the grounded coil. Either the lamp, megger, or magneto method may be used.

300-4.7.10.5 Ground in dc Armature Windings. A ground in a dc generator or motor armature which has neither too high nor too low a resistance can be located by smoking it out as described in paragraph 300-4.7.10.3. If the ground cannot be smoked out, lift all the brushes from the commutator except one pair. Connect this pair to a dc lighting circuit through an incandescent lamp, or use two dry cells or other low voltage source. Connect one terminal of a low reading voltmeter to the shaft, and with the other touch each commutator bar in turn. If there is a ground, there will be two or more bars with practically zero readings. Some of these are the real and the others the phantom grounds. Mark all with chalk. Rotate the armature a few degrees and test again. The real grounds will be in the same bars as before, while the phantom grounds will shift to other bars. The ground is in a coil connected to the bar which shows a real ground with the lowest voltage reading. The lamp test may be used if a few coils at a time are unsoldered from the commutator risers and insulated from the risers by thin pressboard wrapped around each armature coil lead. When the lamp lights at any particular lead, it can be traced back to the grounded coil. If Gas Tungsten Arc Welding (GTAW) welded connections are used, it may not be practical to use the lamp test to detect a faulty coil. In this case use the above chalk and voltage test.

300-4.7.10.6 Moisture Grounds. Grounds in ac or dc machines which are due solely to moisture and not to an actual breakdown of insulation may be baked out, using one of the methods described in paragraphs 300-5.3.1 through 300-5.3.8.

300-4.7.11 OPEN CIRCUITS. Open circuits in ac stator windings are usually due to damaged connections at the ends of the windings where coils and circuits are connected together, and can sometimes be found by visual inspection. Where this does not suffice, resistance measurements between the phase terminals will reveal the presence of open-circuited coils. When the open circuit is an inaccessible location and cannot be reached for repairs, the machine can be repaired for emergency use by cutting out the open-circuited coil as described in paragraph 300-4.7.13.

300-4.7.11.1 Field Windings. Open circuits which develop in the field winding of either an ac or dc generator which is carrying load are indicated by the immediate loss of load and voltage. Open circuits in the field winding of a dc motor may be indicated depending upon circumstances, by one or more of the following symptoms: increase in motor speed, excessive armature current, heavy sparking, and stalling of the motor. A machine with an open-circuited field winding should be secured immediately and examined to locate the open circuit. Open circuits in field windings usually occur at the connections between poles and can be detected by visual inspection. Furthermore, open circuits in the coils themselves usually produce enough damage to permit detection by visual inspection. If, however, an open-circuited coil cannot be located by visual inspection, it can be found by connecting one or two dry batteries to the terminals of the field winding and using a low-range voltmeter to measure the difference of potential between the terminals of each coil. The open-circuited coil will be the one which has the greatest difference in potential between its terminals.

300-4.7.11.2 dc Armature Windings. Open circuits in dc armatures usually result from a poorly soldered connection between the coils and the commutator risers. When the location of an open circuit is not immediately apparent, it can be located as follows:

1. Secure the machine and remove all brushes except those of one positive brush holder and an adjacent negative brush holder.
2. Connect these brushes to a dc lighting circuit with a lamp, lamp bank, or electric heater in series (Figure 300-4-11) or use a battery or other suitable low voltage dc power source in series with a resistance. A larger current will be needed for satisfactorily testing large machines than for testing small machines. For large machines, a dc welding set is a suitable low-voltage high-amperage source of current. Adjust the current, if need be, until the millivoltmeter readings obtained as described below are roughly one-third to one-half the full scale of the millivoltmeter. Make sure, however, that the current does not exceed one-fourth that normally carried by one set of brushes.
3. Use a millivoltmeter to measure the voltage drop between two adjacent commutator bars. With the armature left in a fixed position, move the voltmeter leads from one pair of adjacent bars to the next until a test has been made on all the parts of bars included between the brushes. Turn the armature to bring different bars between the brushes and test these bars. Repeat as often as necessary to test all around the commutator.

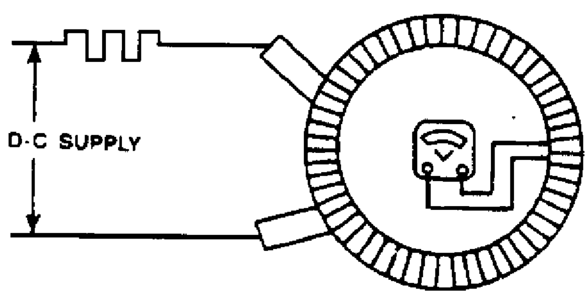


Figure 300-4-11 Open Circuit Locator Setup

300-4.7.11.2.1 No open circuit in the armature winding is indicated in either of the following two cases:

a. All voltage readings are only a small fraction of the voltage between the brushes and are equal within the limits of measurements. Most of the armatures used on naval ships will give readings of this kind when the winding is free of faults.
b. The readings, while not all equal, are only a small fraction of the voltage between the brushes and follow each other in a regular repeating pattern, such as O, R, O, R, O, R, and so on, where R is a reading different from zero. This case is comparatively rare but may be encountered at times since a duplex winding will give readings of this kind even when free of faults. A further test of such windings should be made by measuring the voltage drops between bars 1 and 3, 2 and 4, 3 and 5, 4 and 6, and so on. These readings should be equal, within the limits of measurement, if the winding is free of faults.

300-4.7.11.2.2 An open circuit in the winding is indicated in either of the following two cases:

a. The voltmeter reading across one pair of bars is substantially equal to the voltage between the brushes while zero readings are obtained on several pairs of bars on each side of the pair which gives the high reading. In this case, the open-circuited coil is connected to one or both (depending upon the type of winding) of the bars in the pair which gives the high reading.

b. The voltmeter readings increase (or decrease) in magnitude as the voltmeter leads are moved along from one pair of bars to the next and are alternately plus and minus. In this case a duplex winding is indicated and a further test should be made by measuring the voltage drops between bars 1 and 3, 2 and 4, 3 and 5, and so on. When a reading approximately equal to the voltage between the brushes is obtained, the open-circuited coil is located since it is connected to one or both of the bars in the pair which give the high reading. (For temporary repairs, see paragraph 300-4.7.13.)

300-4.7.12 SHORT CIRCUITS. A short circuit in the stator of an ac machine will be indicated by smoke, flame, or odor of charred insulation. Secure the machine and feel the ends of the coils before they have time to cool. The shorted coil will be perceptibly hotter than those adjacent to it. As a temporary repair, a shorted coil in an ac stator can be cut out until a new coil can be installed. See paragraph 300-4.7.13.

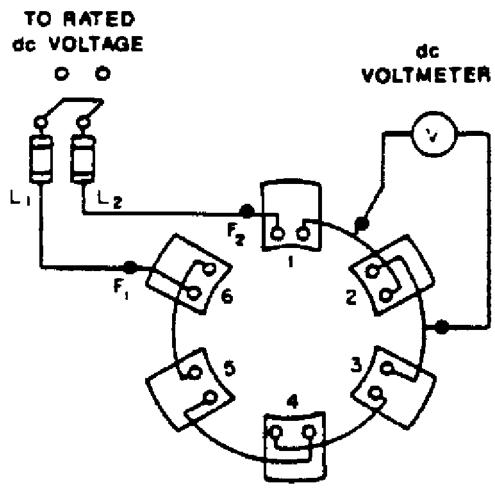
300-4.7.12.1 Field Windings. Short circuits in field coils may be indicated by:

a. Vibration due to unbalanced magnetic pull

b. Smoke or the odor of burning insulation if the short circuit is severe

c. The necessity for increasing field current in generators to maintain normal voltage with the machine running at normal speed.

300-4.7.12.1.1 Locating Shorted Field Coils. To check for short circuits in field coils of a dc motor, apply normal current through the field circuit and measure the voltage drop across each field coil as shown in Figure 300-4-12. If the voltage drop across the coils are equal, it can be assumed that all coils are free of shorted turns, a shorted turn in one coil causes its voltage and that of the adjacent coils to be noticeably lower than the average value. If the voltage drop on any coil is 10 percent lower than the average, one or more the turns may be shorted. As an example, if the shunt field of a generator as shown in Figure 300-4-12, normally operated on 120 Vdc, and the voltages drop across each field is as shown below, it will indicate that coil No. 3 has shorted turns.



Direct current voltage drop test for a shunt field that normally operates on 120VDC.

Coil No.	Voltage
1	21
2	20
3	16
4	20
5	22
6	21

Figure 300-4-12 Field Coil Arrangement to Check for Short Circuits

300-4.7.12.2 dc Armature Windings. A short circuit in a dc armature will be indicated by smoke and the smell of burning insulation. If the armature is readily accessible, the short-circuited coil can be detected immediately after stopping the machine because this coil will be much hotter than the others. In other cases, a short-circuited coil may be located by evidence of charred insulation. Another way of locating short circuits is to use the bar-to-bar test described for open circuits in 300-4.7.11.2. No short circuit is indicated if the voltmeter readings are equal within the limits of measurement. If the readings between bars follow the pattern O, R, O, R, O and so on where R is a reading different from zero, a duplex winding is indicated. In this case, measure the voltage drops from bar 1 to 3, 2 to 4, 3 to 5, and so on. No short circuit is indicated if these readings are equal. When a short circuit is present, the interpretation of the indication given by readings between adjacent bars for simplex windings. or between alternate bars for duplex windings, depends upon whether the armature has a lap or wave winding. If the armature has a lap winding, a voltmeter reading considerably lower than the others indicates a short-circuited coil connected between the pair of bars which gives the low reading, or a short circuit between the bars themselves. If the armature has a wave winding, a short-circuited coil will cause low readings to be obtained between as many pairs of bars as there are pairs of poles. Look for the short circuit in a coil connected to any bar in the pairs which give low readings.

300-4.7.13 EMERGENCY REPAIR. When a machine has an open-circuited or a short-circuited coil in either a dc armature, or an ac stator, or the rotor of a wound rotor induction motor, an emergency repair can be effected by cutting out the damaged coil. This will permit the machine to be restored temporarily to service until permanent repairs can be made, which should be done as soon as possible. To cut out a coil, disconnect both ends of the coil, and install a temporary jumper between the two points from which the coil was disconnected. Then cut the coil at both the front and rear of the armature or stator, as the case may be. Insulate all conducting surfaces exposed by the change in connections, and securely tie all loose ends to prevent vibration.

300-4.7.14 BANDING WIRE. Banding wire on dc armatures should be checked frequently to see that the wires are tight, are not physically damaged, and have not moved from their original position. Also check the clips to see if solder has loosened. If repairs are necessary, duplicate as far as possible the banding wire size, material, and method of assembly used by the manufacturer. Use only pure tin for soldering banding wire. Glass banding materials usually consist of parallel strands of continuous-filament fibrous-glass treated or impregnated with a solventless heat reactive resin of the polyester, epoxy, or acrylic type, and furnished in the form of a tape. This material has been found useful as direct replacement for steel wire bands normally used for holding armature coils in place. The purpose of any band, whether steel wire or fibrous glass, is to accomplish the following:

1. Restrain the end winding against rotational centrifugal force
2. Hold the coils firmly in place to withstand the electromagnetic vibrations
3. Reduce end winding movement to a minimum thus preventing premature failure of the insulation

300-4.7.14.1 Disadvantages. The known disadvantages of steel wire bands are as follows:

a. Adequate insulation must be provided under the steel band to prevent shorting the conductors.
b. Nonmagnetic steel wire must be used to minimize the effects of eddy currents.
c. Band failure can result in winding failure due to lashing action of the broken wire.

300-4.7.14.1.1 The use of glass bands eliminates these problems. Detailed instructions on the use and application of glass bands are shown in Appendix D. Strict adherence to these instructions should result in providing satisfactory glass bands for rotating electrical equipment.

300-4.7.15 END WINDINGS. Periodically (approximately once a year), inspect all end windings and repair all insulation showing signs of chafing or other damage. See that there is adequate clearance between the end windings and the end brackets or any air deflecting shields. Thoroughly clean the end windings if their appearance indicates that this is necessary. No varnish should be applied after cleaning if the insulation appears to be in good condition and the insulation resistance is high. If the insulation appears to be in poor condition or the insulation resistance is low, the equipment should be removed at the first opportunity for a shop overhaul which should include thorough cleaning and the application of baking varnish by dipping and baking (see paragraphs 300-4.5.8.2 through 300-4.5.8.4). In intermediate cases where the condition of the insulation does not appear to warrant a shop overhaul, or when such overhaul is not feasible, the end windings may be varnished in place after cleaning and drying. An air-drying varnish (see paragraph 300-4.5.8.5) should be used and should be applied only by brushing, not by spraying all parts of the end windings which can be reached with a brush. Two thin coats are better than one thick coat. Be sure that the varnish is of the proper consistency for brushing, and that the first coat is thoroughly dry before the second is applied. Care should be taken that no varnish is brushed on electrical contact surfaces where it will tend to insulate them and prevent the flow of current. When applying varnish to the end windings of a dc armature, all brushes should be removed and the commutator should be wrapped with canvas.

300-4.7.16 COOLERS FOR MOTORS AND GENERATORS. When a machine overheats with a water inlet temperature of 29.4° C (85° F) or lower, and when inspection of equipment indicates satisfactory air flow through the machine, a check should be made of the heat being removed by the cooler.

300-4.7.16.1 Overheating Check. A check for overheating requires measurement of the temperature differential between the cooler inlet and outlet water. The value obtained should be compared with the factory performance test value, which generally is included in the motor and generator technical manual. If the factory test value is not available, comparison should be made with an identical machine. Values compared should be for the same load condition and should be stabilized values. If the rise in water temperature is greater than for comparable factory tests or greater than for an identical machine, the water flow through the cooler is inadequate and should be corrected.

300-4.7.16.1.1 Inadequate water flow may be caused by partial plugging of the water side of the cooler tubes, which should be cleaned in accordance with the instructions in **NSTM Chapter 254, Condensers, Heat Exchangers, and Air Ejectors** . Inadequate water flow also may be the result of reduced pump pressure, or it may be the result of improperly sized piping or other restrictions in the piping system, in which case the matter should be referred to NAVSEA. If the machine is overheating and the rise in water temperature is equal to or less than reported in factory tests or less than for identical machines, the transfer of heat from air to water has been impaired and the cause, aside from restricted air flow through the machine, may be dust and dirt accumulated on the air side of the cooler tubes. When the air side of the cooler tubes requires cleaning, the individual tube bundles can be removed from the machine and washed with hot water or cleaned with a stream jet. In rare instances, loss of heat transfer may be caused by inadequate contact between the inner and outer cooler tubes as a result of manufacturing error. In such cases, the cooler should be replaced.

300-4.7.16.2 Double-Tube-Type Cooler Leakage. For double tube type coolers, a test of the leakage warning system should be performed. Air pressure 5 lb/in^2 will be sufficient to indicate the tightness of this system. As a first step, apply pressure to one end of the leak-off compartment of the coolers, leaving vent and drain at the opposite end open, to blow out the intertube passages. Repeat the procedure applying air pressure to that compartment at the other end to blow out in the opposite direction. Then apply a 5 lb/in^2 air pressure test on the leakage warning system. The pressure should be held for 5 minutes to check for any drop in pressure during this time.

300-4.7.16.2.1 A leak between an inner tube and the tube sheet allows water to seep from the cooler head through the leaky joint into the leak-off compartment and out the leakage drain. To locate such a leak, remove the cooler heads and plug all drains and vent connections to the leak-off compartment except one. Connect air at approximately 5 lb/in^2 to the remaining connection, and apply soap solution to the circumferential joints between the inner tubes and the tube sheet. Formation of soap bubbles at any joint indicates a loose fit. To tighten, roll the tube end with the inner tube expander. Roll just enough to get a tight joint. Do not roll excessively.

300-4.7.16.2.2 A leaky inner tube allows water to seep into the slots in the outer tube where it is carried to the leak-off compartment and out the leakage drain. To locate a leaky tube, apply soap films which stretch across and seal both ends of the inner tubes. The tube or tubes with leaks will be indicated by the formation of a soap bubble at both ends of each leaky tube when air at 5 lb/in^2 pressure is applied to the leak-off compartment as described in paragraph 300-4.7.16.2. In making this test, care must be taken to see that both ends of each tube are sealed with a soap film since a soap bubble will not form at one end of a leaky tube if the other end is open and allows air to escape freely.

300-4.7.16.3 Single Tube-Type Cooler Leakage. Leaks in single tube-type coolers are more difficult to locate than leaks in double tube-type coolers. Fortunately this type of cooler is not extensively used for naval applications although it is found in generators or motors of a few electric drive propulsion installations.

300-4.7.16.3.1 To test a tube in single tube-type cooler for leaks, tightly plug one end of the tube with a rubber stopper and apply low pressure air to the inside of the tube by inserting a nozzle with a rubber collar tightly into the other end of the tube. The nozzle connection should be supplied with a shut-off valve and a pressure gage between the valve and the nozzle which fits into the tube end. As soon as enough air has been admitted to raise the pressure inside the tube to about 10 lb/in^2 , shut off the valve and watch the pressure gage. A leak in the tube is indicated if the pressure gage shows a drop in pressure. In making the test it is essential that the plug and nozzle make tight connections, and that the valve be tight.

300-4.7.16.3.2 A test for leak between a tube and the tube sheet in a single tube-type cooler can be made by a modification of the foregoing test. Instead of sealing one end of the tube with a plug inserted into the end of the tube, use a flat piece of metal with an annular rubber gasket fastened to one side. The inside diameter of the gasket should be slightly larger than the diameter of the joint between the tube and tube sheet so that when the gasket is held tightly in contact with the tube sheet, air pressure inside the tube will reach the joint between the tube sheet. Apply air under pressure from the other end of the tube as described in paragraph 300-4.7.16.3.1. If the pressure gage shows a drop in pressure after the valve is shut off, there is a leak in the tube, or in the joint between the tube sheet and the end of the tube which is covered by the piece of metal and gasket. The test must be repeated to test for a leak between the other tube sheet and the other end of the tube. The test of paragraph 300-4.7.16.3.1 will show whether or not there is a leak in the tube itself. If the leak is in the joint, roll the tube end as described in paragraph 300-4.7.16.2.

300-4.7.16.4 Repair. Whenever a leaky tube is found in either a double or single tube-type cooler, both ends of the tube should be plugged with the plugs carried for this purpose. A number of tubes in a cooler section can be plugged in this way without seriously affecting the total heat dissipating capacity. When the number of plugged tubes becomes large enough to keep the cooler from producing the required amount of cooling, the cooler core should be replaced.

300-4.7.16.5 Corrosion. Zinc plates or rods, where installed, are provided in air coolers to protect the cooler tubes from corrosion. Electrolytic action takes place between the zinc and seawater and the zinc is gradually eaten away. A zinc inspection routine should be established for each air cooler based on the rapidity with which the zincs are consumed. This interval should not exceed 90 days and in some cases may be considerably shorter. Zincs should be kept clean and should be replaced when they are one-half consumed. To remove the zincs for inspection, it is first necessary to drain the cooler to avoid discharging water on and possibly into the machine.

300-4.7.16.6 Gaskets. Gaskets should be tightened or renewed when necessary. However, do not tighten the nuts excessively. Leaks may sometimes occur at gasket joints between cooler heads and tube sheets when excessive twisting forces are exerted by connected piping. When a unit is to be secured for a considerable length of time, the cooler should be treated in accordance with the instructions contained in **NSTM Chapter 254, Condensers, Heat Exchangers, and Air Ejectors** .

300-4.7.17 REPLACING PARTS. Measure the insulation resistance of spare armatures for dc machines, of spare rotating fields for ac machines, and of spare coils for both ac and dc machines before using them to replace damaged parts. When replacing ac stator or dc armature coils, always drive the old slot wedges outward from the center toward each end and the new ones toward the center from each end.

300-4.7.17.1 Installation. The new coils may be rubbed lightly with paraffin to facilitate their installation in the slots. The coils should go in the slots with only very light taps with a rawhide mallet. To avoid damage to the insulation, do not use a wooden mallet or metal hammer and never use heavy blows. In soldering, be very careful that no drops or lumps of solder fall into other connections or behind the commutator risers, where they may cause a short circuit. Do not use an acid for flux; it may damage the insulation. Use rosin dissolved in alcohol or other noncorrosive soldering paste. Before soldering the coil connection to the commutator risers, it is advisable in all cases to band the armature and insert wooden wedges to tightly fill the spaces adjacent to the commutator risers to which connections will be soldered. The wooden wedges are removed after the soldering is complete.

300-4.7.17.2 Balancing. After installing a new coil or rebanding an armature, it should be balanced before putting in operation.

300-4.7.18 HANDLING DURING DISASSEMBLY AND ASSEMBLY. Whenever it becomes necessary for maintenance or other reasons, to disassemble and reassemble a motor or generator, the procedure outlined in the manufacturer’s instruction books should be strictly followed.

300-4.7.18.1 Equipment Protection and Safety. The greatest care shall be exercised when handling the machines to prevent damage to any part. The machine rotors (ac revolving field or dc armature) should be supported, while being moved or when stationary, by sling or blocking under the shaft or by a padded cradle or thickly folded canvas under the core laminations. When lifting the rotor, use rope slings under each end of the shaft (but not under the journals) and use a spreader between the slings to prevent their coming in contact with the ac rotor or dc armature coils. If the construction of the shaft is such that there is no room for a sling except around the journals, see that the journals are properly protected by heavy paper or canvas before applying the sling. If the whole unit (stator and rotor) is to be lifted by lifting the stator, make sure that the bottom of the air gap is tightly shimmed unless both ends of the shaft are supported in bearings. This is to prevent the armature or rotor resting on field poles or stator core.

300-4.7.18.2 Transportation. Caution shall be exercised in transporting parts to prevent jostling of the windings lest the insulation be damaged with resultant burnout. Rough handling, or careless use of bars or hooks, often causes more damage to a machine during disassembly or reassembly than such a machine receives in years of general use.

300-4.7.18.3 Balancing. All rotating elements of motors, generators, or motor generators are carefully balanced in the manufacturer’s plant prior to assembly. This reduces vibration, noise, radio interference, wear of slip rings, commutators, and brushes and improves the overall electrical and mechanical performance. The balance tends to become worse in normal service due to shock and vibration. It is affected every time the bearings are replaced, armature rewound, commutators or slip rings are turned, or the rotating elements are unduly jarred during removal or maintenance. In order to obtain optimum performance, it is desirable to rebalance the rotating elements every time that they are removed for maintenance work.

300-4.7.19 PERIODIC TEST AND INSPECTIONS. When PMS is installed, conduct preventive maintenance in accordance with MRCs. Maintenance should not be confined to the repair and replacement of units which have failed. A systematic schedule of test and inspection, cleaning, adjustment, and repair is essential for long life of machines and maximum reliability. Because of its inaccessible location, it may not be possible to carry out a complete maintenance schedule on some shipboard equipment. However, the schedules given for generators and motors should be followed so far as practical, and should be supplemented by additional or more frequent tests and inspections if indicated by experience. For periodic tests and inspections on propulsion equipment see **NSTM Chapter 235, Electric Propulsion Installations** ; for ball bearings see **NSTM Chapter 244, Propulsion Bearings and Seals** .

300-4.7.19.1 Daily. Perform the following:

1. Check oil level and condition of oil rings in oil-ring lubricated bearings, and the flow of oil (by sight gage) in force-feed lubricated bearings.
2. Inspect motor and generator surroundings for dripping water, oil, steam, acid, excessive dirt, dust, or chips, and loose gear which might interfere with ventilation or jam moving parts.
3. Observe running motors for vibration and unusual or excessive noise. When the normal noise of the driven auxiliary is not excessive, a more detailed observation of motor noises may be made, if necessary, by holding the ear to one end of a tool, rod, or pipe, with its other end held on the motor frame.
4. Examine each running generator set for cleanliness, vibration, unusual or excessive noise, heating, and condition of brushes, commutators, collector rings, bearings, bolts, and mechanical fastenings.

300-4.7.19.2 Weekly. Perform the following:

1. Inspect brushes for proper seating and freedom of movement in brush holders, cleanliness of brush holders and brush rigging, condition and tightness of brush pigtails and brush antishock guards, and proper brush alinement, including correctness of staggering.
2. Inspect commutators of idle machines for commutator condition. Remove inspection plates if necessary. A highly polished brown-black finish indicates a good condition (see paragraph 300-4.7.8).
3. Inspect collector rings of idle machines for evidence of corrosion.
4. Inspect all running motors for unusual sparking. Remove inspection plates if necessary.
5. Check the automatic starting and voltage buildup of each emergency generator. This test shall be conducted using the emergency generator start test switch on the emergency switchboard.
6. Run each ship service generator at partial or full load, whichever is the more convenient, for at least 30 minutes once a week. Record in the log. Observe the behavior of the set in accordance with paragraph 300-4.7.19.1, step 4. If it is not practical to run each ship's service set every week because of naval shipyard work, extensive overhaul, or casualty, an entry shall be made in the log stating the facts.
7. Blow out generators which have been in use with clean, dry, compressed air and wipe with a lintless cloth. The best time to do this is immediately after a generator has been secured.
8. Check insulation resistance of ship's service and emergency generators if the generator has been idle for a week or longer. Check also any associated rotary exciters. Insulation resistance measurements also should be made each time the machine is secured. When taking these measurements, personnel should take all safety precautions necessary. They should avoid any unnecessary exposure to live terminals if the switchboard must be opened to obtain these readings. Separate measurements of ac generator stator and rotor circuits shall be made. The measurements for ac generator stators shall include cables between the generator and the generator circuit breaker. This measurement shall be from any phase lead to the frame of the switchboard or other good ground in the vicinity. In some recent ships, the casualty power circuit breaker is connected between the generator and the generator circuit breaker. It is possible to obtain the reading for the stator at these casualty power circuit breakers located on the generator switchboard. After obtaining readings through casualty power terminals, be certain the casualty power circuit breaker is opened. On other ships where the casualty power

circuit breaker does not make connection between the generator and the generator circuit breaker, readings may be obtained at the fuses supplying the control power or the metering potential transformers. These transformers are connected between the generator and the generator circuit breaker. At such terminals, it is usually possible to make connections with a minimum of exposure to live terminals. The readings for ac generator's fields and associated rotating exciters should be taken at the ac generator. This can be done without lifting the brushes from the slip rings for machines with rotating exciters. For machines with static exciters, the brushes must be lifted and only the rotor tested. For test on static exciters, see the applicable equipment instruction book. Readings can then be taken for the field from the slip rings to the rotor. When combined ac generator field and rotating exciter resistance is taken without lifting the slip ring brushes and is found to be below the allowable value for ac generator field and rotating exciter complete armature circuit, separate readings for the ac generator and rotating exciter should be taken by lifting the slip ring brushes. Readings for the ac generator field can be then taken between the slip ring and ground and readings for the exciter complete armature circuit can be taken between the slip ring brush holder and ground. The insulation resistance readings for dc generators shall include the complete armature circuit and the leads to the generator circuit breaker. The dc generator readings shall be taken at the switchboard if this can be done safely. Otherwise, the readings may be taken at the generator. Readings shall be made between a lead and the nearest available good ground. Insulation resistance readings on any generator should be taken just after the machine is shut down. Under these conditions, the readings should not be less than the following:

a AC generators:

Stator - 0.5 megohms

Rotor only (field) - 0.5 megohms

Rotating exciter complete armature circuit - 0.2 megohms

AC generator field and rotating exciter - 0.2 megohms

b DC generators

Complete armature circuit and leads - 0.2 megohms Measurements taken at other temperatures should also exceed the same minimum values. If readings are below allowable, refer to paragraphs 300-3.2 through 300-3.2.7 for basic information on insulation resistance measurements and paragraphs 300-3.4.3 through 300-3.4.11.1 for additional guidance in determining if insulation levels are satisfactory.

300-4.7.19.3 Monthly. Perform the following:

1. Run each generator continuously for at least four hours once a month at full rated load and voltage. Record in the log. If it is not practical to apply full load, the maximum load possible should be used, and an entry should be made in the log, giving the load that was used and the reason why full load was not practical. If it is not practical to run each generator for this test every month because of naval shipyard work, extensive overhaul, or casualty, an entry should be made in the log stating the facts.

2. Inspect zincs in air coolers (see paragraph 300-4.7.16.5).

3. Remove the drain plugs that are provided in Navy class A spraytight, watertight, and submersible motor enclosures to drain off any water that may have collected in the enclosures because of condensation of water vapor. Be sure to replace the drain plugs immediately after draining the motor enclosures as otherwise the protection afforded by the enclosures will be lost. The draining of the motor enclosure should be noted in the log together with an entry loosely describing the amount of water drained off as none, a few drops, a cupful, or so forth as appropriate.

300-4.7.19.4 Quarterly. Perform the following:

1. Inspect pulleys, belts, belt guards, mounting frame bolts, end shield bolts, and mechanical fastenings for mechanical soundness and tightness.
2. Check clearance between bearings and shaft (sleeve bearings only).
3. Check air gaps if accessible for measurement (on machines with sleeve bearings only). Where bearing wear is measured quarterly, check of air gaps (on machines with sleeve bearings) is not required except where machine alignment has been disturbed.
4. Check distance of brush holders from the commutator. The nearest part of the brush holder should be not more than 1/8 inch or less than 1/16 inch from the commutator.
5. Check brush pressure. This should be between 1-1/2 and 2-1/2 lb/in^2 of contact area (see paragraph 300-4.7.7.1.4).
6. Make sure that the brushes move freely in the holders and that the holders are clean.
7. Insulation resistance measurements (see paragraphs 300-3.2 through 300-3.2.7 and 300-3.4 through 300-3.4.11.1) shall be made on motors which are used infrequently or which because of their usage and location demand special attention. Insulation resistance measurements shall also be made for each of the following situations:
   a Whenever physical damage has occurred.
   b Whenever there is evidence of a contaminant such as oil or salt water leaking on the motor.
   c Before starting motors which are located in severe environments and failures of these motors have been experienced due to low insulation resistance.
8. For three phase, ac motors, the insulation resistance of one phase only need be measured. The leads between the motor and controller shall be tested with the motor. If the insulation resistance is less than 1 megohm for ac motors or 0.5 megohm for dc motors, the motors should be scheduled for cleaning. If insulation resistance is less than 0.2 megohm for ac motors and 0.1 megohm for dc motors operation of the motors should be avoided, if practical, and action should be taken to find and remedy the cause of the low insulation resistance.
9. Operate motors at normal load and temperature.
10. Insulation resistance measurements of motor generators shall be made quarterly. The procedures and the basis of acceptance are the same as given in paragraphs 300-4.7.19.2, step 8 and 300-4.7.19.4, step 7.

300-4.7.19.5 Semiannually. Perform the following:

1. Drain, flush out, and renew oil in sleeve bearings.
2. Add grease to ball bearings if required. See **NSTM Chapter 244, Propulsion Bearings and Seals** . Record the date and the fact that the machine was lubricated on this date.
3. Inspect all gaskets, particularly bearing lubricant seals. Replace worn gaskets and seals.
4. Inspect armature banding and slot wedges.
5. Inspect the connections of armature coils to commutator risers.
6. Inspect and tighten electrical connections, particularly connections at equipment terminals, connections between coils, and connections to slip rings.
7. Inspect commutator clamping ring.
8. Clean out slots in the commutator, and undercut mica if necessary.

9. Thoroughly clean all generators.
10. Inspect fans for loose or broken blades.

300-4.7.19.6 Annually. Perform the following:

1. Inspect all windings and insulation and clean and repair insulation as necessary.
2. Inspect and test generator air coolers. See paragraphs 300-4.7.16.5 and 300-4.7.16.6.
3. Measure insulation resistance on all permanently installed portable type tools, appliances (such as bracket fans), and cable assemblies. The insulation resistance shall be 1 megohm or more; if not, corrective action shall be taken.
4. Blow out and clean motors thoroughly to remove dirt from commutator, ventilation ducts, and insulation (see paragraph 300-4.5.2).

300-4.8 MAINTENANCE OF SWITCHBOARDS, WIRING DISTRIBUTION BOXES, AND CONTROL EQUIPMENT

NOTE

Where PMS is installed, preventive maintenance shall be conducted in accordance with MRCs.

300-4.8.1 INSPECTION. Loose electrical connections or mechanical fastenings have caused numerous derangements of electrical equipment. Loose connections can be readily tightened, but it requires thorough inspection to detect them. Consequently, at least once a year and during each overhaul, each switchboard, propulsion control cubicle, distribution panel, bus transfer equipment, and motor controller should be deenergized for a thorough inspection and cleaning of all bus work and equipment. Inspection of deenergized equipment should not be limited to visual examination but should include touching and shaking electrical connections and mechanical parts to make sure that the connections are tight and mechanical parts are free to function. Particular attention should be paid to the following points:

a. Ensure that all electrical connections and mechanical fastenings are tight. Where space permits, a torque wrench should be used when tightening bolts. Over-tightening can be as detrimental as under-tightening. Refer to **NSTM Chapter 075, Threaded Fasteners** , for torquing procedures and precautions. Torque values for the more common bolt sizes used in switchboard construction are contained in Table 300-4-7. Torque values are minimum and should not be exceeded by more than 10 percent. Fasteners which are inaccessible to use of a torque wrench should be checked for tightness visually and, if possible, with a conventional wrench or by hand. Split-ring lockwashers, where used, should be verified to be fully compressed by means of direct visual examination or by using a hand held inspection mirror. Torque tests need not be performed if torque seals or insulating paint has been applied on the fasteners as the torque testing of the connections will only damage the seal. Loosening of connections in these cases can be identified by broken seals or cracked paint. However, it is advisable to periodically check electrical connections covered with insulating varnish using thermographs, since cracked varnish is not always visible.
b. See that mechanical parts are free to function.
c. See that no loose tools or other extraneous articles are left in or around switchboards and distribution panels.

d. Check the supports of bus work and make sure that the supporters will prevent striking of bus bars of different polarity, or bus bars and grounded parts during periods of shock.

e. Check the condition of control wiring and replace if necessary.

Table 300-4-7 COMMON BOLT SIZE TORQUE VALUES

	Torque Requirements (ft/lb)		
Bolt Size (in)	**Steel**	**Silicone Bronze**	**Copper**
Bus Bar Bolts			
3/8	14	10	-
1/2	30	15	-
5/8	50	35	-
Circuit Breaker Studs			
3/8	-	-	7
1/2	-	-	15
5/8	50	-	-
3/4	-	-	25
1	130	-	-
1-1/8	-	-	40

f. Clean the bus work and the creepage surfaces of insulating materials, and see that creepage distances are ample. If damaged, taped switchboard bus bars should be retaped as necessary in accordance with **NSTM Chapter 320, Electric Power Distribution Systems** .

g. See that there are no obstructions to ventilation of rheostats and resistors. Replace broken or burned-out resistors. A light coat of petrolatum may be applied to the face-plate contacts of rheostats to reduce friction and wear. Make sure that no petrolatum is left in the spaces between the contact buttons as this may cause burning and arcing. Check all electrical connections for tightness, and wiring for frayed or broken leads. Service commutators and brushes for potentiometer-type rheostats in accordance with instructions for dc machines.

h. Adjust the pointer of each switchboard instrument to read zero when the instrument is not connected and make sure that the pointer does not stick at any point along the scale. Check instrument for accuracy whenever they have been subjected to severe shock. Repairs should be made only by the manufacturers, shore repair activities, or tenders. See **NSTM Chapter 491, Electrical Measuring and Test Instruments** , for detailed instructions on instruments.

i. Make sure that fuse clips make firm contact with fuses; lock-in devices (if provided) are properly fitted; and all fuse wiring connections are tight.

j. Inspect for cable routed near bolt heads or nuts. When such a situation is found, the cables should be inspected for adequate bracing that will support the cables during shock and short circuit conditions. If sufficient slack exists in a cable such that the cable could contact a bolt, nut or other sharp object which could cut the cable insulation under shock or short circuit conditions, the situation must be corrected. The activity should install additional supports, modify the hardware configuration, or install insulation caps, or other protective material, to remove the possibility of cable damage. These requirements should not be construed to require minimizing slack that is provided for future relugging of cables. This slack, however, must be adequately braced or protected.

300-4.8.1.1 Adjacent Installations. Inspections should not be confined to switchboard and distribution panels, but should also include adjacent installations which may cause serious casualties. Rubber matting in the way of switchboards should be inspected for signs of deterioration such as cracks in the material and separation at the seams. Ventilation openings located to permit water to discharge onto electrical equipment, insufficient insulation overhead to prevent heavy sweating, need for drip-proof covers and spray shields, and location of water piping and flanges where leakage could spray onto switchboards and other gear are examples of installations which could cause casualties. Action should be initiated to have unsatisfactory conditions corrected.

300-4.8.1.2 Distribution Boxes. Wiring distribution boxes (fused), with and without switches, which feed vital circuits should be checked annually. Tighten fuse clip barrel nuts and terminal connections. On a new ship and after a major overhaul, tighten and prick punch loose bus bar nuts on the backs of insulating bases.

300-4.8.1.2.1 The phosphor-bronze fuse clip and supplementary bent-wire fuse retainer have been superseded by a steel copper-clad silver-plated fuse clip. The steel fuse clips do not require fuse retainers to prevent dislodgement of fuses under shock and vibration. The wire fuse retainers impose a hazard of possible accidental dislodgement and falling into bus work to cause short circuits. To eliminate this hazard on both vital and nonvital circuits that require frequent removal of fuses, and where difficulties occur with loosening of existing phosphor-bronze fuse clips and wire fuse retainers, they should be replaced with steel copper-clad silver-plated fuse clips having the following type designations: FC21CF 30 amperes (NSN 5999-00-904-6654; FC21DF 30 amperes (NSN 5999-00-789-3049); and FC21EF 60 amperes (NSN 5999-00-752-6501). Do not remove the wire retainers until the new type steel fuse clips are on board for substitution. Tighten the fuse-clip barrel nut until the arch in bottom of the steel fuse clip is drawn flat.

300-4.8.1.3 Mounted Rheostats. Plate type rheostats are usually insulated from ship ground by means of insulating spools at rheostat feet. This eliminates the possibility of electrical malfunction due to low resistance to ground (see paragraph 300-4.4.1.1); however, this does present a definite shock hazard. Therefore, the following precautions should be taken:

a. All handwheel setscrew openings should be sealed with insulating compound.
b. All exposed metal attachments to the handwheel shaft should be eliminated (changed to nylon).
c. Check to see if adequate clearance (at least 1/2 inch) is maintained between shaft and cabinet.
d. All exposed plates should be provided with a metal shield, grounded, to prevent touching a hot plate.
e. All cabinet mounted plates should carry a warning tag on the cabinet exterior stating that the rheostat plates may be hot.

300-4.8.2 SWITCHBOARD AND DISTRIBUTION PANEL CLEANING. Wiping with a dry cloth will usually be sufficient for cleaning bus bars and insulating materials. A vacuum cleaner, if available, can also be used to advantage. Care should always be exercised to make sure that the switchboard or distribution panel is completely deenergized and it will remain deenergized until the work is completed. Cleaning energized parts should be avoided because of the danger to personnel and equipment. Always observe electrical safety precautions when cleaning or working around switchboards. (See Section 2.)

300-4.8.2.1 Cleaning Agent. Soap and water should not be used on the front panels of live front switchboards or on other panels of insulating material. Use a dry cloth.

300-4.8.2.2 Front Panel Cleaning. The front panels of dead front switchboards may be cleaned without deenergizing the switchboard. Wiping with a dry cloth is usually all that is needed to clean the panels. A damp soapy cloth may be used for grease and fingerprints. The surface should then be wiped with a cloth dampened in clear water to remove all soap and dried with a clean, dry cloth. The cloths used in cleaning must be wrung out thoroughly so that no water is left to squeeze out and run down the panel. A small area at a time should be done and then wiped dry.

300-4.8.2.3 Insulation Resistance Check. Insulation resistance values for an isolated switchboard after cleaning shall be not less than 1 megohm between each bus and ground. If the value is less than 1 megohm, corrective action shall be taken to isolate the low resistance.

300-4.8.2.4 Precautions When Performing Switchboard Maintenance. If maintenance on the switchboard consists of cutting, drilling, or installing or removing small parts, the parts and debris shall be collected either by installing a sheet of protective material under the area to be worked to capture falling parts or debris, or by sticking a wad of soft putty behind the area to be drilled or cut to capture the debris.

300-4.8.2.5 Switchboard Inspections After Maintenance. In addition to the criteria set forth in paragraph 300-4.8.5.6, switchboards should be inspected per the applicable technical manual after any major maintenance, Ship-Alt, or A&I, especially if the maintenance involves drilling or cutting the switchboard or switchboard cover.

300-4.8.3 CIRCUIT BREAKERS, CONTACTORS, AND RELAYS. Circuit breakers should be carefully inspected and cleaned at least once a year and more frequently if subject to unusually severe service conditions. A special inspection should be made after a circuit breaker has opened a heavy short circuit.

300-4.8.3.1 Power Removal. Before working on a circuit breaker, control circuits to which it is connected should be deenergized. Draw-out circuit breakers should be switched to the open position and removed before any work is done on them. Disconnecting switches ahead of fixed-mounted circuit breakers should be open before any work is done on the circuit breaker. Where disconnecting switches are not provided to isolate fixed-mounted circuit breakers, the supply bus to the circuit breaker should be deenergized, if practical, before inspecting, adjusting, replacing parts, or doing any work on the circuit breaker. If the bus cannot be deenergized, observe the precautions of paragraph 300-2.5.

300-4.8.3.2 Contact Cleaning. Contacts in circuit breakers, contactors, relays, and other switching equipment should be clean, free from severe pitting or burning, and properly alined. Occasional opening and closing of contacts will aid cleaning and sealing. Remove surface dirt, dust, or grease with a clean cloth moistened, if required, with appropriate cleaning agent. See paragraph 300-5.2.3 through 300-5.2.3.4 for information on safety precautions. (Silver alloy contacts should not be filed or dressed unless sharp projections extend beyond the contact surface. Such projections should be filed or dressed only to the contact surface.) When cleaning and dressing contacts, maintain the original shape of the contact surface and remove as little material as possible.

300-4.8.3.3 Contact Surface Inspection. Inspect the silver alloy contact surface. Burning, erosion, or overheating is not acceptable and the contact will need to be replaced. Slight burning, pitting, or erosion is acceptable. Carbon deposits should be removed using a dry, lint-free cloth. Use scotchbrite to loosen deposits. Do not use emery cloth, file, or sandpaper. If the contacts have deep pitting that penetrates through the contact surface or 50 percent of the contact surface, replace the contacts.

300-4.8.3.4 Cleaning Breaker Mechanism Surfaces. Clean all circuit breaker mechanism surfaces, particularly insulation surfaces, with a dry cloth or air hose. Be sure that water is blown out of the air hose, that the air is dry, and that pressure is not over 30 lb/in^2 before directing on the breaker.

300-4.8.3.5 Inspection of Moving Parts. Inspect pins, bearings, latches, and contact and mechanism springs for excessive wear or corrosion and current carrying parts for evidence of overheating. Bolt-on parts/attachments and subassemblies may be replaced by ship's force personnel. Replacement of parts that require major disassembly or sub-assembly teardown shall be accomplished by an overhaul facility or shipyard with circuit breaker repair capability.

300-4.8.3.6 Operational Check. Slowly open and close circuit breakers a few times manually. See that trip shafts, toggle linkages, latches, and all other mechanical parts operate freely and without binding. Make sure that the arcing contacts meet before and break after the main contacts. If poor alinement, sluggishness, or other abnormal condition is noted, adjust according to the technical manual for the circuit breaker.

300-4.8.3.7 Lubrication. Lubricate bearing points and bearing surfaces, including latches, with a drop or two of lubricating oil per MIL-L-17331 (Military symbol 2190 TEP). Wipe off excess oil.

300-4.8.3.8 Final Inspection and Insulation Resistance Check. Before returning a circuit breaker to service, inspect all mechanical and electrical connections including mounting bolts and screws, draw out disconnect devices, and control wiring. Tighten where necessary. Give final cleaning with cloth or compressed air. Operate manually to make sure that all moving parts function freely. Check insulation resistance.

300-4.8.3.9 Sealing Surfaces. Sealing surfaces of circuit breaker, contactor, and relay magnets should be kept clean and free from rust. Rust on the sealing surfaces decreases the contact force and may result in overheating of the contact tips. Loud humming or chattering will frequently warn of this condition. Lubricating oil per MIL-L-17331 (Military symbol 2190 TEP) wiped sparingly on the sealing surfaces of the contactor magnet will aid in preventing rust.

300-4.8.3.10 Use of Oil. Oil should always be used sparingly on circuit breakers, contactors, motor controllers, relays and other equipment, and should not be used at all unless there are specific instructions to do so or oil holes are provided. If working surfaces or bearings show signs of rust, the device should be disassembled and the rusted surfaces carefully cleaned. Lubricating oil per MIL-L-17331 (Military symbol 2190 TEP) may be wiped on sparingly to prevent further rusting. Oil has a tendency to accumulate dust and grit which may cause unsatisfactory operation of the device, particularly if the device is delicately balanced.

300-4.8.3.11 Arc Chute Maintenance. Arc chutes should be cleaned by scraping with file if wiping with a cloth is not sufficient. Replace or provide new linings when broken or burned too deeply. See that arc chutes are securely fastened and that there is sufficient clearance to ensure that no interference occurs when the switch or contactor is opened or closed.

300-4.8.3.12 Flexible Parts. Shunts and flexible connectors which are flexed by the motion of moving parts should be replaced when worn, broken, or frayed.

300-4.8.4 OPERATING TESTS. Operating tests consisting of operation of equipment in the manner in which it is intended to function should be made regularly. For the intended function of a device, refer to the complete switchboard or equipment assembly wiring diagram since the control wiring scheme may differ from that shown in the technical manual or detail drawing applicable to the specific device.

300-4.8.4.1 Circuit Breakers. For manually operated circuit breakers, the test consists of simply opening and closing the breaker to check mechanical operation. For electrically operated circuit breakers, the test should be made with the operating switch or control to check both mechanical operation and control wiring. Care must be exercised during these operating tests not to disrupt any electric power supply vital to the operation of the ship, nor to endanger ship's personnel by inadvertently starting motors or energizing equipment being repaired.

300-4.8.4.2 Bus Transfer Equipment. For manual bus transfer equipment the test is made by manually transferring a load from one power source to another, and checking mechanical operation and mechanical interlocks. For semiautomatic equipment, the test should also include operation by the control pushbuttons. For automatic equipment, the test should include operation initiated by cutting off power (opening a feeder circuit breaker) to see if an automatic transfer takes place. The precautions given for circuit breaker operating tests should be observed when testing bus transfer equipment.

300-4.8.4.3 Overload Relays. During periodic inspections of motor controllers, or at least once a year, overload relays should be examined to determine that they are in good mechanical condition and that there are no loose or missing parts. The size of overload heaters installed should be checked to determine that they are of the proper size as indicated by the motor nameplate current and heater rating table. Any questionable relays should be checked for proper tripping at the next availability and replaced if necessary. See **NSTM Chapter 302, Electric Motors and Controllers** , for a description of the various types of overload relays.

300-4.8.4.4 Control Circuits. These circuits should be checked to ensure circuit continuity and proper relay, contactor, and indication lamp operation. So many types of control circuits are installed in naval ships that it is impractical to list any definite operating test procedures. In general, certain control circuits, such as those for the starting of motors or motor generator sets, or voltmeter switching circuits, are best tested by using the circuits as they are intended to operate. When testing such circuits, the precautions listed in paragraph 300-4.4 should be observed to guard against damage to the associated equipment. Protective circuits such as overcurrent, or reverse current circuits usually cannot be tested by actual operation because of the danger to the equipment involved. These circuits should be visually checked and, where possible, relays should be operated manually to make sure that the rest of the protective circuit performs its desired functions. Extreme care must be taken not to disrupt vital power service or damage electrical equipment. Reverse power relays should be checked under actual operating conditions. With two generators operating in parallel, the generator whose reverse power relay is to be checked should be made to take power from the other generator. The reverse power relay should trip the generator circuit breaker in 10 seconds or less after the reverse power relay starts to operate. If the relay fails to function, the generator circuit breaker should be tripped manually to prevent damage to the prime mover. To make a generator act as a load, it is necessary to restrict the flow of steam to the steam turbine or fuel to the diesel or gas turbine. Restricting the flow of steam or fuel can be accomplished by reducing the speed control setting slowly until the generator begins to absorb power and act as a motor.

300-4.8.4.5 Emergency Switchboards. These should be tested regularly according to the instructions on the switchboard, in order to check the operation of the automatic bus transfer equipment and the automatic starting of the emergency generator.

300-4.8.4.6 Submarine dc Circuit Breakers - Nondrawout Type. Calibration of circuit breakers on all active submarines has been accomplished. There should be no need for periodic checking of the calibrated setting. However, in the event of the necessity for complete circuit breaker replacement or replacement of an overcurrent tripping device, onboard calibration should be conducted on the affected unit. If rearrangement results in relocation of a breaker or modification to the connecting bus work or cables, onboard calibration is required. The adjustment of a circuit breaker should not, under any circumstances, be altered by other than qualified personnel (wherever practical, a manufacturer's representative is recommended). A copy of the calibration data should be supplied to the submarine for record purposes. The following test procedure should be used.

300-4.8.4.6.1 Power for the test is to be obtained from the ship's batteries. The number of cells in series to give the desired short-circuit current is determined as follows. Measure the external circuit resistance, and using the nominal cell voltage and an internal resistance of about 50 micro-ohms per cell, plot a curve of short-circuited current versus the number of cells in series. From the curve, read the number of cells to give any desired test current. However, since the current output of the battery will vary with its state of charge, check this curve immediately after developing the first oscillograph record of an actual current obtained and correct the curve if necessary. The combination of cells to be used will be those whose arrangement as installed will best facilitate the fewest and the shortest possible jumpers. The jumpers to be used are standard battery cell jumpers. The battery cells not in use should be isolated from those in use by removing the cell connectors between them.

300-4.8.4.6.2 As a precaution to protect equipment and cables in case the circuit breaker being tested fails to open, a backup circuit breaker is to be connected in series with the circuit breaker under test. The circuit breakers to be tested fall into two categories with respect to backup protection.

300-4.8.4.6.3 In testing battery circuit breakers and those auxiliary-power circuit breakers which are connected on the battery side of the battery circuit breaker, a backup circuit breaker should be placed on the dock. For this application of backup protection, both the short-time and instantaneous trip mechanisms should be rendered inoperative. Thus, the circuit breaker is used as a remote controlled short-circuiting switch. Operation of this circuit breaker should be accomplished electrically using the closing coil and shunt trip. A separate source of control power should be provided for this purpose. This circuit breaker should be connected in series with the propulsion bus using a minimum of 2400 MCM (MCM = 1,000 circular mils) in each leg. The two poles of this circuit breaker should be connected in parallel to keep contact wear to a minimum. Care must be taken to protect personnel and equipment from the high dc currents and strong magnetic forces tending to whip the cables. All connections must be tight and all cables must be secured to prevent whipping.

300-4.8.4.6.4 Direct current ships service auxiliary-power circuit breakers connected on the load side of the battery circuit breaker may be tested using the battery circuit breaker for backup protection. As above, the automatic trip devices should be rendered inoperative and a separate source of control power should be provided for operating the battery circuit breaker electrically as a backup protection.

300-4.8.4.6.5 A 4,000-ampere (or larger), 50-millivolt shunt should be connected into the circuit to carry the entire short-circuit for metering.

300-4.8.4.6.6 An oscillograph should be used for recording the test results. Oscillograph elements should be placed across the 4,000-ampere shunt, across the contacts of the circuit breaker under test, and across the contacts of the backup circuit breaker. A 60-Hz wave should be recorded on the oscillograph film to serve as a time base.

300-4.8.4.6.7 Telephone communications should be established at all stations.

300-4.8.4.6.8 To establish that these circuit breakers are operating satisfactorily it is necessary to show that the overcurrent trip mechanisms of each pole of the circuit breaker will trip the circuit breaker in accordance with the time-current characteristic and that none of the overcurrent trip mechanisms will trip the circuit breaker at a current below the lowest trip setting. To accomplish this, the following test, where applicable, should be run on each circuit breaker to be tested.

1. On each pole individually (trip mechanisms on poles not under test tied down).
   - a Test current approximately 50 percent above the specified long time delay pick-up setting. The circuit breaker should trip between 10 and 30 seconds. If the circuit breaker does not trip as specified, a manufacturer's representative or another qualified person should adjust the circuit breaker calibration. This will be followed by as many retests and adjustments as are necessary to make the operation satisfactory at this point. Adjustment should be accomplished with as few retests and with as short a test time as possible in order to keep the ampere-hour discharge on the battery low.
   - b Test current not less than 30 percent above the specified short time delay pick-up point. The circuit breaker should trip within the time range specified by the curve. Test and adjust as necessary to obtain proper operation.
   - c Test current approximately 30 percent above the specified instantaneous pick-up point. The circuit breaker should trip in 10 cycles or less. Test and adjust as necessary to obtain proper performance.
2. On all poles together (all trip mechanisms in operation).
   - a Test current 20 to 25 percent below the specified instantaneous pick-up point (if the instantaneous pick-up setting of the circuit breaker is less than 10 times the continuous current rating, use 10 to 15 percent). The circuit breaker should perform as specified by the applicable curve. It should not trip instantaneously. If instantaneous tripping occurs, determine the trip mechanism at fault and adjust as necessary.
   - b Test current 10 to 15 percent below the specified short time delay pick-up point. The circuit breaker should perform as specified by the applicable curve. Adjust if necessary.
   - c Test current 10 to 15 percent below the specified long time delay for 1 minute. The circuit breaker should not trip. Adjust if necessary.

300-4.8.5 TEST AND INSPECTION FREQUENCY. Conditions of service, and age and condition of equipment differ from ship to ship. Consequently, it is impractical to provide a rigid schedule of tests and inspections which will be equally applicable to every ship. The engineering force on each ship should establish a schedule for that ship based on past experience and suggestions given below. Frequent recurrence of trouble indicates that the interval between tests and inspections should be shortened. The following suggested schedule will serve as a guide to the approximate frequency of tests and inspections.

300-4.8.5.1 Every Hour. Inspect the ground detector voltmeter or ground detector lamps while using the voltmeter or lamps to test for grounds.

300-4.8.5.2 Monthly. Perform the following:

1. Test bus transfer equipment (see paragraph 300-4.8.4.2).
2. Test emergency switchboards (see paragraph 300-4.8.4.5).

300-4.8.5.3 After Firing, If Practical. Inspect switchboards and distribution panels (see paragraph 300-4.8.1.2).

300-4.8.5.4 Every 2 Months. Perform the following:

1. Test circuit breakers (see paragraph 300-4.8.4.1).
2. Test control circuits (see paragraph 300-4.8.4.4).

300-4.8.5.5 Every 6 Months. Reverse power relays.

300-4.8.5.6 Yearly and After Each Overhaul. Perform the following:

1. Inspect and clean switchboards and distribution panels (see paragraphs 300-4.8.1 through 300-4.8.2.2).
2. Check overload relays (see paragraph 300-4.8.4.3).
3. Visually inspect ground connections to insure that a ground connection exists and that it is securely fastened with good metal-to-metal contact (see paragraph 300-2.2.1.4.1).

300-4.8.5.7 Prior to Start Up. Check plate type rheostats for low insulation resistance. If low (under 0.5 megohms) dry out before energizing system.

300-4.9 STATIC FREQUENCY CHANGERS

300-4.9.1 INTRODUCTION. Static Frequency Changers (SFC's) are power conversion systems which electronically convert 60-Hz, Type I power to 400-Hz, Type III power. Another type of system which performs the same function mechanically is the rotating 400-Hz alternator driven from a 60-Hz ac motor. Present practice is to use static frequency changers because they perform better, are more reliable, weigh less, and occupy less floor space. In addition, static frequency changers do not require extensive space for system removal, as is mandatory with rotating equipment. Type III power is desired by many sophisticated systems because of its stability and close regulation tolerance limits. The input voltage to a frequency changer may change over a wide range with relatively little change in output voltage or frequency. In addition, the output load current of a frequency changer may change over a wide range, with relatively little change in output voltage or frequency. Frequency changers also have characteristics which allow rapid regulation of voltage and frequency for changing input voltage or changing load current.

300-4.9.2 INPUT/OUTPUT CHARACTERISTICS. The input power to a frequency changer is 450-Vac, 3 Phase, 3 wire, ungrounded, 60-Hz, Type I power. The frequency changer has input characteristics which classify it as a nonlinear load, and could introduce harmonics of 60-Hz on the power line. With the equipment powered by a 60-Hz, Type I power source and supplying any load from no-load to rated-load, the total current harmonic content shall be not more than 5 percent of the rated-load input current. Individual harmonic currents from the 2nd harmonic through the 32nd harmonic shall be not more than 3 percent. Individual harmonics above the 32nd harmonic until the 333rd harmonic, shall not be more than 100/n percent, where n is the number of the harmonic.

a. Output Power. The output power of a frequency changer is described as a kilowatt (kW) rating, which is output power in watts divided by 1000. The rated output power of a frequency changer is defined at a specific power factor (p.f.) which signifies the phase relationship between the output current and voltage. A typical rating of a frequency changer would be:

   Rated output power, kW_{rated} = 150 kW at apower factor of 0.8 lagging This definition then requires the designation of the frequency changer maximum volt ampere product divided by 1,000, or kilovolt amperes(kVA). This is the maximum product of voltage output and output current that the frequency changer may handle, at any power factor.

Rated output kVA_{max} = Rated kW/ratedpower factor As an example:

Rated output kVA_{max} = 50kW/0.8 = 187.5 Kilovolt amperes.

b. Output Voltage. The output voltage of a frequency changer is 450-Vac, 3 Phase, 3 wire, ungrounded, 400-Hz, Type III power. Total harmonic content of the output voltage must be less than 3 percent, and any one harmonic between the 2nd and the 32nd harmonic must be less than 2 percent. Output harmonic content of the voltage waveform is reduced by filtering techniques. Output voltage regulation must be less than or equal to ± 0.5 percent for an input voltage change of ± 5 percent or an output load current change of 0 to 125 percent.

c. Output Current Rating. The relationship of the output current of a frequency changer to its maximum output power and voltage is:

I_{max} (line) = kW_{max} x 1,000 / (E(line-to-line) x √3) where:

$kW_{(max)}$ = The maximum power capability of the SFC, in kilo-watts.

$I_{(max)}$ (line) = The balanced maximum line current in any one output line, in amperes.

E(line-to-line) = The balanced nominal line-to-line voltage of any one output lines, in volts. An example of the current a 150 kW rated frequency changer with aline-to-line voltage of 450 volts is:

$I_{(max)}$ (line) = (150 x 1000)/

(450 x √3) = 192 amperes

d. Feeder Circuit Coordination. One of the greatest differences between a rotating alternator and a static frequency changer producing the same voltage is the inability of the static frequency changer to tolerate unlimited load surge current. The basic elements of the frequency changer produce the output voltage with solid state switches, which have a limited ability to operate at a finite maximum current. If this current is exceeded, the result is catastrophic failure. As a result, static frequency changers are protected with fast-acting circuits called current limits, which will operate to protect the frequency changer from allowing more current than can be safely handled. As an example, a 150 kVA air-cooled frequency changer will handle a 300 percent current (596A) overload for 0.1 seconds after which the output voltage will drop to zero to protect the frequency changer from catastrophic damage. The current limit circuits are exceptionally fast, and do an excellent job of protecting the frequency changer from an overload condition. The design characteristics of the frequency changer will protect the frequency changer,but may be inconsistent with performance of rotating sources. Rotating sources typically provide larger overload currents than static frequency changers and still maintain output voltage. As a result, circuit breakers on feeder lines can isolate a fault or short circuit, with little disturbance to other feeder circuits when the power source is a rotating generator. This is inconsistent with the operation of the static frequency changer where the current limiting circuits will operate so rapidly, that before a fault can be isolated, all feeder circuits will experience voltage collapse due to current limiting action. As a result, 400 Hz systems supplied from static frequency changers may require a circuit modification to include a current limit device (CLD). CLD's cause a high impedance to be electronically inserted into a feeder circuit line to (1) limit fault current and (2) isolate the fault such that other feeders do not experience catastrophic voltage decrease. After CLD's are tripped by down-stream faults, interrupters must be tripped to isolate the fault by shunt trip elements, and not the typical current-time overcurrent characteristics of regular circuit breakers. Dedicated loads which are fed by one frequency changer do not need a CLD, as the current limit response will protect both the load and the frequency changer from overload. See Figure 300-4-13.

e. Loading Effects. The output power of frequency changers is 400-Hz, which is more than six times the frequency of Type I, 60-Hz power. The 400-Hz frequency, when used in power conditioning systems, is easier to electronically manipulate than lower frequencies, and also requires smaller transformers for isolation purposes. Line impedances, however, are more than six times higher than for 60-Hz systems, which tends to give undesirable loading effects when power from a frequency changer is used at great distances from the source. The increase of load currents at distant loads could cause voltage variations outside specifications of the frequency changer due to the relatively large, intervening line impedance, i.e., the frequency changer will regulate voltage very well and consistently at its own terminals but not well at distance loads. To give some control of this low voltage at distant loads, frequency changers have means to boost the voltage at distant loads to compensate for loading effects.

300-4.9.3 TYPICAL MAJOR COMPONENTS. The technique used in static frequency changers to produce the 400-Hz output is to convert the 60-Hz, 3-phase input to dc voltage by rectification, and then to invert the dc voltage to the 400-Hz desired output 3-phase voltage with a solid state inverter. Other elements of the SFC are input and output electro-magnetic interference (EMI) filters, and input transformer. See Figure 300-4-14.

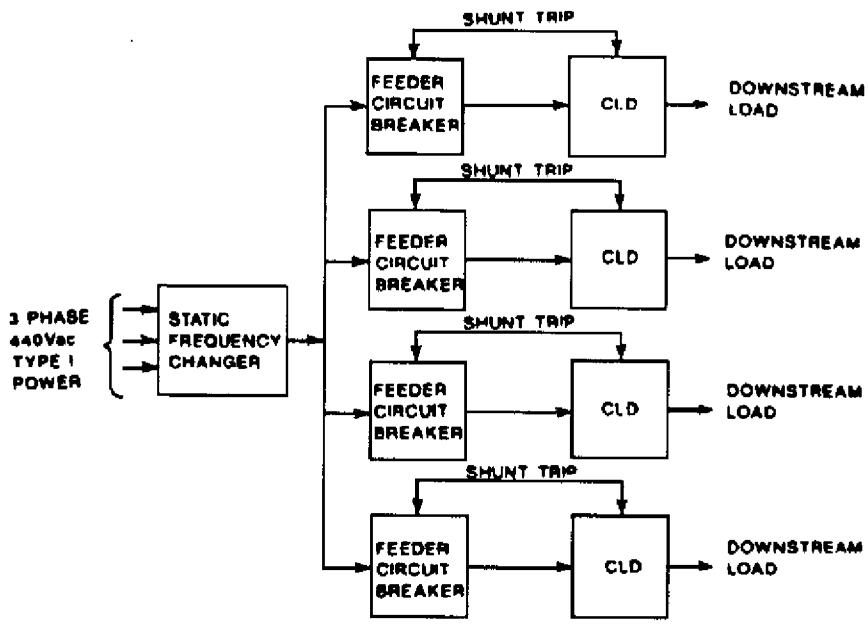


Figure 300-4-13 SFC with Isolating CLD's

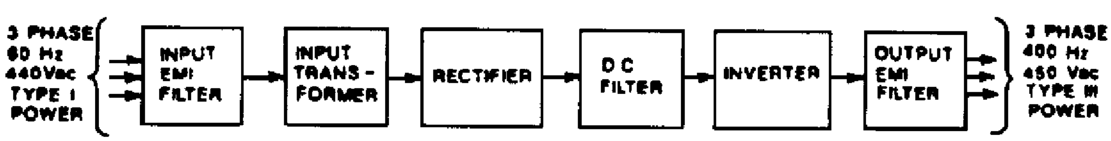


Figure 300-4-14 Major SFC Components

a. Rectification. The ac input power is converted to dc power by means of 3-phase rectification. The usual connection is that of a fully-controlled bridge. In this type of connection the phase control is performed in all the six legs of the bridge. The magnitude of the dc voltage is regulated by changing the firing angle (phase control angle) of the Silicon Controlled Rectifier (SCR) in each leg. There are six SCRs, two per phase, in a 3-phase bridge. Furthermore, a transformer is commonly connected between the ac source and the rectifier bridge with the purpose of providing both the desired ac voltage level, and isolation from the ac source. The 3-phase bridge connection delivers a dc voltage containing six pulses per each cycle of the ac source. With the purpose of reducing the harmonic content in the ac input current and in the dc output voltage, most frequency changers use rectifier connections that provide 12 or 24 pulses per cycle. This design is less-costly, more reliable, and occupies less volume than increasing the size of the filters that otherwise would be required to comply with NAVSEA harmonic requirements. There are many types of possible rectifier connections that would deliver the required number of pulses. However, the most common connection utilizes two 3-phase bridges connected in parallel and they deliver an output with 12 pulses per cycle.

1 Single-Phase Bridge Connection. This connection is shown in Figure 300-4-15 and it delivers two pulses per cycle of the ac source; that is, the output ripple frequency would be 120 hertz when the input power is 60 hertz. When terminal 1 of T1 is at a higher potential than terminal 2, the current path is: terminal 1, diode CR4, load resistor, diode CR3, and terminal 2. When terminal 2 of T1 is at a higher potential than terminal 1, the path is: terminal 2, diode CR2, load resistor, diode CR1, terminal 1. The load current is commutated between diodes CR4 & CR2 and between diodes CR3 & CR1. The commutation does not occur instantaneously, but is delayed by the reactance of the ac source, the transformer, the bridge, and the load. The delayed commutation produces the overlap angle which is proportional to the commutating reactance. In a single-phase bridge the diodes in anyone of the bridge legs conduct half of the time or 180 electrical degrees per cycle. Furthermore, the commutation occurs simultaneously in the plus and negative side of the bridge, and diodes CR4 & CR3 (or CR2 & CR1) always conduct at the same time.

2 Three-Phase Bridge Rectifier Connection. This connection is shown in Figure 300-4-16 and it delivers six pulses per cycle of the ac source; that is, the output ripple frequency would be 360 hertz. In the plus side of the bridge, the conducting leg must be the one connected to the phase with the highest potential with reference to neutral (real or virtual) at that instant, and in the negative side of the bridge, the conducting leg must be the one connected to the phase with lower potential. Assume that the sequence of the line voltages in the secondary of T1 is 1-2, 2-3, 3-1. When terminal 1 of T1 has the highest potential and terminal 2 the lowest, the current path initially is: terminal 1, CR2, load resistor, CR3, and the potential of terminal 2 the current is commutated, in the negative side of the bridge, from CR3 to CR5. Next, the potential of the bridge is commutated from CR2 to CR4. In fact, there are commutations going on in both sides of the bridge, but not simultaneously. They are displaced by 60 electrical degrees. Each leg conducts one third of the time or 120 electrical degrees per cycle. Any phase control introduced to regulate the voltage, would delay the commutation by an angle usually designate by (alpha) Actually, the commutation is further delayed by the reactance of the commutating path which introduces the overlap angle.

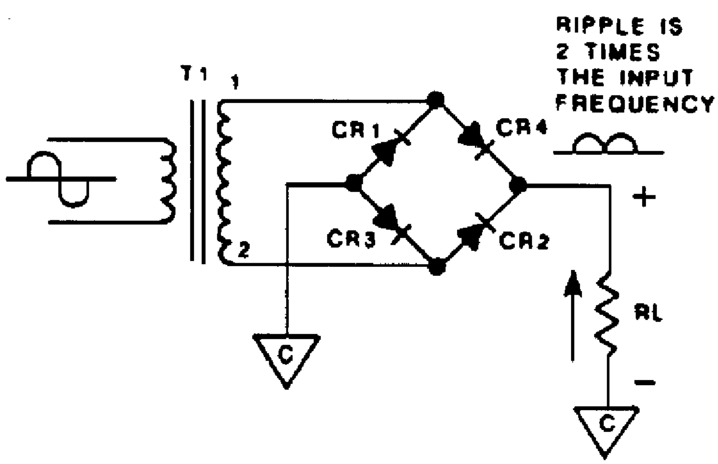


Figure 300-4-15 Single Phase, Full-Wave Bridge Rectifier

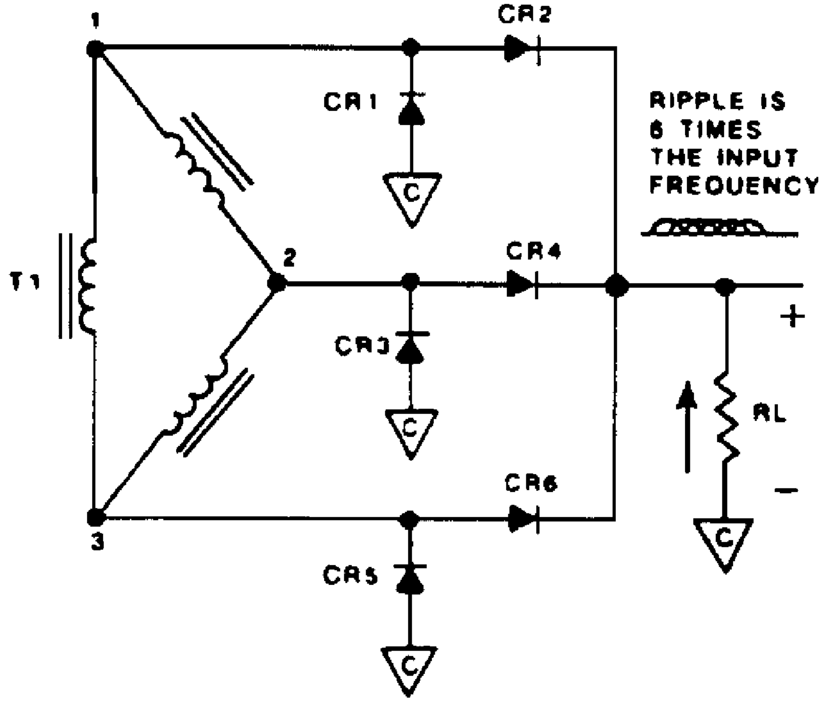


Figure 300-4-16 Three-Phase, Full-Wave Bridge Rectifier

3 Twelve-Pulse Rectifier Connection. There are many ways to achieve twelve-pulse rectification, the connection shown in Figure 300-4-17 is one of them. It consists of two 3-phase bridges and a rectifier transformer that has two sets of secondaries, one of them connected in delta and the other set connected in wye. One of the bridges is fed from the delta and the other from the wye, this combination results in two 30 degree phase shifted bridges, that when connected in parallel produce a dc output voltage with 12 pulses. In other words, the frequency of the dc ripple is 720 hertz

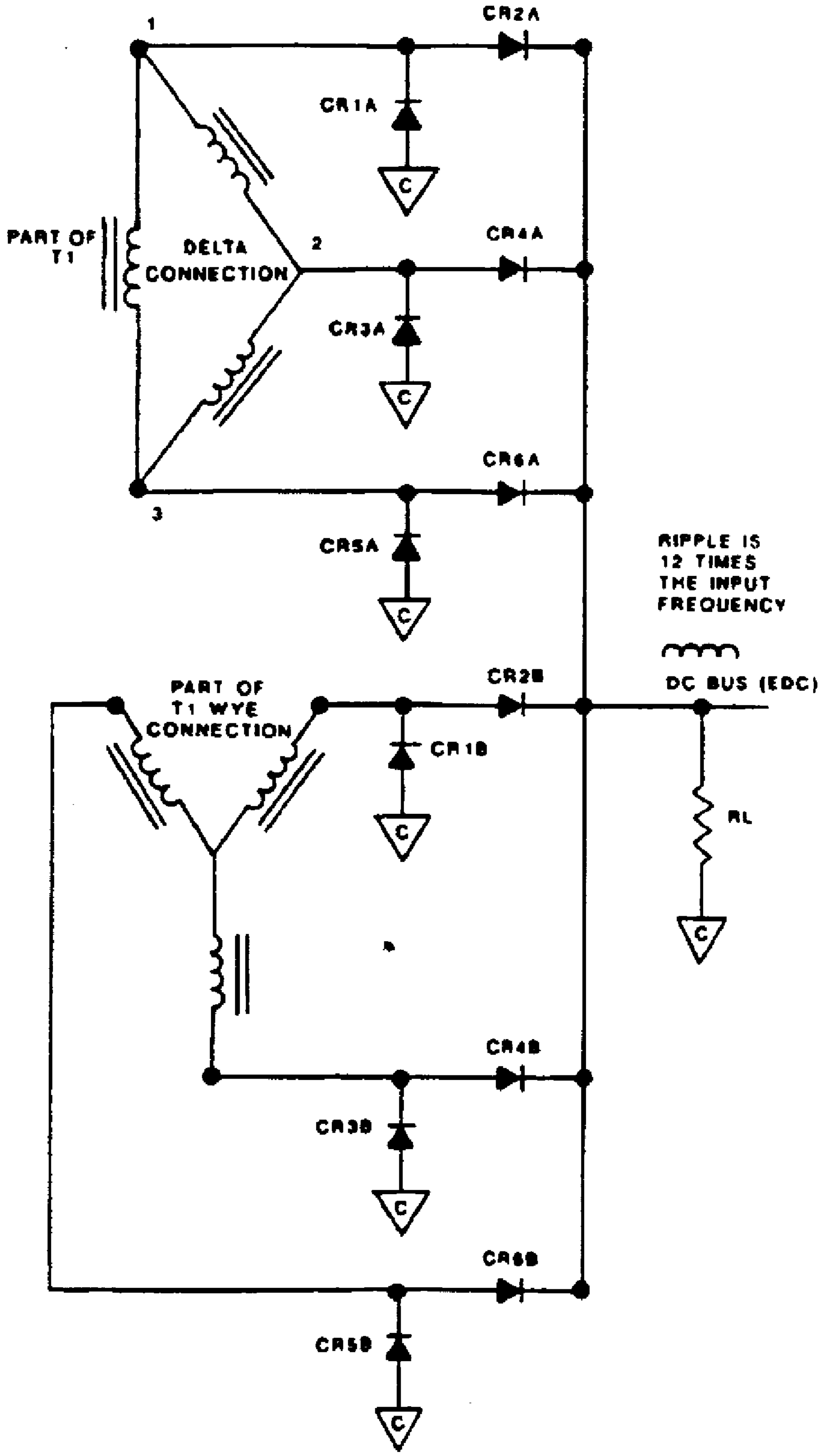


Figure 300-4-17 Six Phase, Full Wave Rectifier with Delta-Wye Connections

4 Half-Bridge Arrangement. To facilitate manufacturing and repairs, and to minimize the space required by frequency converters bridge, there are six identical half bridges per frequency converter, two per phase. In

any phase the upper half-bridge is connected to the delta secondary. This connection is illustrated in Figure 300-4-18. As this figure shows, the rectifier transformer consists of three identical single-phase transformers, one per phase, and each containing one primary and two secondary windings. The primary windings are connected in wye (see Figure 300-4-18) and one set of secondary windings are connected in wye and the other set is connected in delta. Transformers are not part of the half bridge. However, every half bridge also contains an inverter switch. In the connection shown in Figure 300-4-18 the dc voltage delivered to the inverter is regulated by delaying the firing of the SCRs by the proper angle.

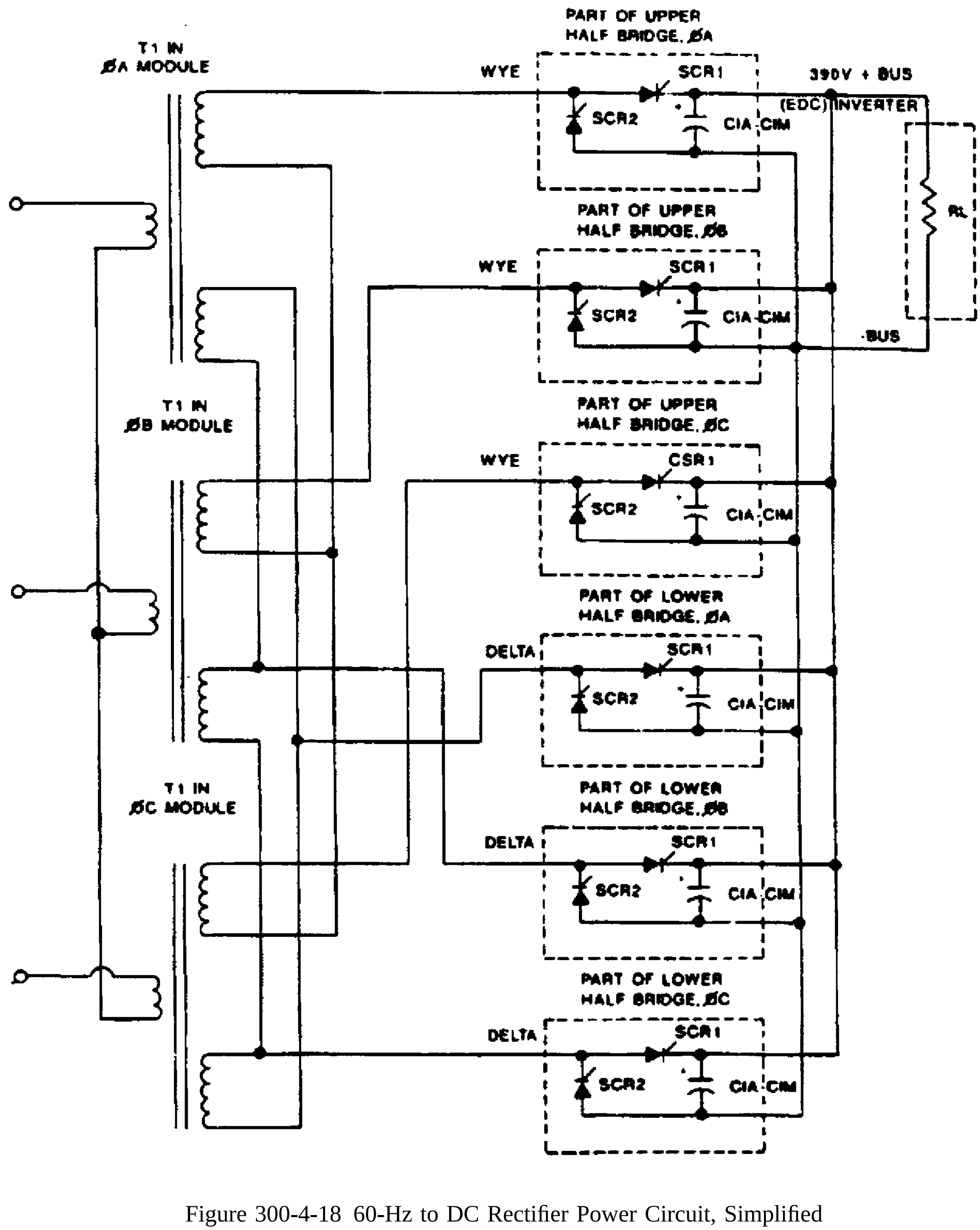


Figure 300-4-18 60-Hz to DC Rectifier Power Circuit, Simplified

b. Inversion. The inversion process uses six solid-state switches to convert the dc voltage of the rectifiers to unfiltered 3-phase, 450-Vac. The inverter may be divided into two groups of switches called inverter poles which are used to generate the inverter phase voltage. The phase output voltage of each pole is square in character. Phase voltages are added to produce line-to-line voltages which become sinusoidal after suitable filtering. The square waves generated by the switches are filtered to the sinusoidal state because the square type pulses are made up of a fundamental desired frequency (400-Hz) and an infinite number of odd, unwanted harmonics which are filtered out. The switching rate of the inverter switches is controlled by an internal clock or oscillator whose frequency is not affected by load current changes and is one of the more desirable performance characteristics of a static frequency changer. This differs greatly from rotating equipment where the frequency or speed of generator rotation is greatly dependent on load current which influences the torque load on the machine. The magnitude of the output ac sinusoidal voltage wave is controlled by varying the amount of phase difference between the two half bridges. Inverter poles may be made up of silicon controlled rectifier (SCR) switches or transistor switches arranged as shown in Figure 300-4-19. The Mark 84 inverter which uses transistors for inversion, arranges the switching devices in a more complex arrangement which yields an excellent output voltage waveform low in harmonic content. (In this instance, the dc voltage input is regulated by phase controlled rectifiers, and output ac voltage is regulated by another means.)

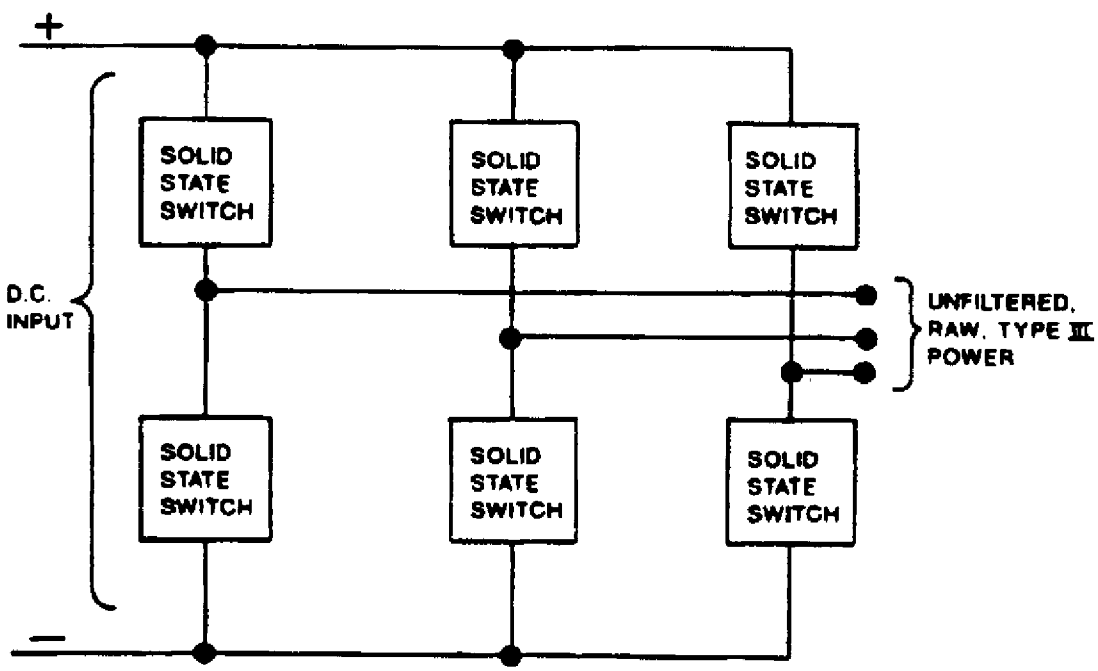


Figure 300-4-19 Basic Inverter Arrangement

300-4.9.4 TYPES OF COOLING. Static frequency changers are cooled either with water-cooling techniques, or blown air. The critical items requiring cooling are transformers, filters, solid-state devices (rectifiers and inverters), as well as low level control electronics. Transformers, filter reactors, capacitor filter elements, and solid-state devices all suffer degradation of life if temperatures are allowed to be excessive. In addition, if solid-state devices are allowed to reach limiting temperatures, catastrophic failures result such that further operation is impossible. The loss of cooling water flow or cooling air flow will result in failure of a solid-state element within minutes. The condition of loss of coolant water flow, or loss of cooling air flow, are cause for frequency changer shutdown by built in alarm detection and activation.

a. Water Cooling. Water cooling of electronic components requires specially prepared water if the water comes into contact with electrified components. The water required for this purpose must be chemically pure and uncontaminated with any elements which would cause current conduction within or through the water. Water for such purposes is referred to as de-ionized water (DI water) and for good heat transfer is required to flow in intimate contact with thermal generating components. Water cooling of solid state power switches is common, and is an efficient method to conduct heat away from such components. Heat caused by losses in the power switches causes the need for its removal in order to keep device operating temperatures within maximum limits. Failure rates of solid state devices are directly proportional to temperature, and the net effect of operating at the limiting temperature is catastrophic failure. It is therefore imperative that all elements of a water cooling system are always totally operable, as small decreases of efficiencies of such systems lead to reliability decrease.

1 Direct cooling of electronic components with water generally involve a later exchange of the heat contained by the DI water with other water such as seawater. In this exchange, the reduction of flow of either the seawater or the DI water is cause for a catastrophic failure or reliability decrease of a solid-state component requiring this cooling method.

2 The cooling of transformers, filter reactors, or filter capacitors by the water cooling method generally does not lead to a catastrophic failure if the flow is reduced as these components are better able to withstand over-temperature without complete failure, but overall reliability is still influenced by excessive temperature.

b. Air Cooling. Cooling of static frequency changer components by air draft is a common and reliable system as long as the air flow is maintained at the required level. The cooling method is the circulation of air over the surface to be cooled, and the two variables involved in the quality of cooling are the size of the surface exposed to the cooling air and the velocity of cooling air movement. For any particular design, surface areas to be used to transfer heat from a heated item are fixed by design of a device heat sink. The important factors in dealing with heat sinks are that the contact between the device to be cooled (such as a solid-state switch) and the heat sink must be maintained over the life of the element. The replacement of a solid-state power device must ensure that the contact between the heat sink and the device is properly made, and that bolting pressure of mechanical systems is adjusted per tech manual requirements. For all components requiring cooling, it is only necessary to maintain air flow at required levels. Cooling air velocity may be maintained by proper maintenance of all filters such that air flow constraints are never allowed to develop.

300-4.9.5 MAINTENANCE CONCEPTS. The maintenance concept for SFC’s includes planned, preventative, and corrective maintenance at the organizational level. The plan also includes monitoring, reporting, grooming, and replacement or refurbishment of selected components at the intermediate level. In general, Depot Level Maintenance Facilities have not been used for the SFC’s.

a. Organizational Level Maintenance. Planned maintenance at the organizational level is conducted in accordance with existing Maintenance Index Pages (MIP) and Maintenance Requirement Cards (MRC’s). These tasks include cleaning, inspection, lubrication, insulation resistance, and standard lay-up maintenance procedures. The Planned Maintenance System (PMS) includes inspection of ground connections, and half-bridge components. Corrective maintenance actions are accomplished through trouble shooting and repair, beginning at the organizational level. These maintenance efforts have consisted primarily of replacing worn or damaged components of the SFC at the piece part level. Each printed circuit board (PCB) is considered a piece part, and will be removed and replaced at the organizational level. Detailed instructions for troubleshooting and repair procedures are outlined in the associated Static Frequency Changer Technical Manuals. The technical manuals include troubleshooting, drawings, and parts lists. In addition, for water cooled frequency changers (150 KVA), Allowance Parts Lists (APL) and ship’s Coordinated Shipboard Allowance Lists (COSAL) were revised by the Ships Parts Control Center (SPCC) to increase On Board Repair Parts (OBRP’s) as necessary to alleviate supply support and maintenance problems for these water cooled units.

b. Intermediate Level Maintenance. Short intermediate level maintenance includes both corrective and preventative maintenance tasks. Preventative maintenance tasks include:

1 Measuring heat dissipation of critical components

2 Inspecting alignment of coolant fitting and hose material condition (water cooled)

3 Calibrating and verifying operation of mechanical and electrical switches, gauges, and meters
4 Inspection of filters and refurbishing
5 Measuring flow rate of cooling water (water cooled)
6 Refurbishment of half-bridge assembly in place
7 Testing of SFC capacitors.

300-4.10 REWINDING COILS

300-4.10.1 MAGNET WIRE SELECTIONS. When rewinding coils for electrical equipment, it is desirable to use wire per Federal Spec. J-W-1177 of the same size with the same type and thickness of insulation as the wire in the original coils. If this is done, the dimensions and the electrical and magnetic characteristics of the coils are not changed. Duplicate wire, is, however, frequently unavailable. In many cases it is satisfactory to use wire (or combinations of wires) of slightly different types. Magnet wire per NEMA Standard Publication No. MW 1000 may be used. Where substitute wire is used, a record shall be kept on the Material History Card (paragraph 300-4.2.3.1) giving the data necessary to identify the original wire and the substituted wire. This record could be useful for the guidance of other repair activities that may have to service the equipment in the future and that may have the original type of wire available. The following data are given to aid in estimating the differences in coil performance and dimensions which are to be expected if the original wire is not duplicated. Factors to be considered in selecting replacement wire are:

a. Cross-sectional area of the conductor or current-carrying capacity of the wire

b. Suitability of the insulation

c. Effect of insulation thickness upon winding space necessary and coil performance

d. Availability of stock.

300-4.10.1.1 Cross-Section. Duplication insofar as possible of current-carrying capacity and ohmic resistance is desirable to keep from changing the coil resistance, heating, and magnetic characteristics. When wire of the desired size is unavailable, several combinations of two, three, or even more wires in parallel may be used to replace larger wires provided that sufficient conductor area is obtained, and sufficient space is available for the additional insulation. The replacement wire or wires should preferably have a conductor area equal to or greater than the area of the original wire. When the available wires do not permit the attainment of at least the cross-sectional area of the original wire, it is permissible, for emergency repairs, to use smaller wires and anticipate increased heating and shortened insulation life of the repaired winding.

300-4.10.1.1.1 Table 300-4-8 gives the cross-sectional area of bare round wires in circular mils. A circular mil is the area of a circle which is one mil (0.001 inch) in diameter. The cross-section of wire conductors is practically doubled by a decrease of three numbers in American Wire Gage (AWG) size. For example, No. 18 wire has an area of 1,620 circular mils and No. 15 wire an area of 3,260 circular mils. If a coil is originally wound with No. 15 wire, two No. 18 wires in parallel will give nearly the same area, 3,240 circular mils as compared to 3,260.

Table 300-4-8 DIMENSIONS AND PROPERTIES OF BARE ROUND COPPER MAGNET WIRE

			Resistance 20°C (68°F)			
AWG or B&S Type Gage	**Diameter of Bare Wire**	**Area in Circular Mils**	**Ohms per 1,000 feet**	**Ohms per Pound**	**Feet per Pound**	**Pounds per 1,000 feet**
1	0.2893	83,690	0.1239	0.000489	3.947	253.3
2	0.2576	66,370	0.1563	0.000778	4.977	200.9
3	0.2294	52,640	0.1970	0.001237	6.276	159.3
4	0.2043	41,740	0.2485	0.001966	7.914	126.4
5	0.1819	33,100	0.3133	0.003127	9.980	100.2
6	0.1620	26,250	0.3951	0.004972	12.58	79.46
7	0.1443	20,820	0.4982	0.007905	15.87	63.02
8	0.1285	16,510	0.6282	0.01257	20.01	49.98
9	0.1144	13,090	0.7921	0.01999	25.23	39.63
10	0.1019	10,380	0.9989	0.03178	31.82	31.43
11	0.0907	8,234	1.260	0.05053	40.12	24.92
12	0.0808	6,530	1.588	0.08035	50.59	19.77
13	0.0720	5,178	2.003	0.1278	63.80	15.68
14	0.0641	4,107	2.5258	0.2032	80.44	12.43
15	0.0571	3,257	3.184	0.3230	101.4	9.858
16	0.0508	2,583	4.016	0.5136	127.9	7.818
17	0.0453	2,048	5.064	0.8167	161.3	6.200
18	0.0403	1,624	6.385	1.299	203.4	4.917
19	0.0359	1,288	8.051	2.065	256.5	3.899
20	0.0320	1,022	10.15	3.283	323.4	3.092
21	0.0285	810	12.80	5.221	407.8	2.452
22	0.0254	642	16.14	8.301	514.2	1.945
23	0.0226	509	20.36	13.20	648.4	1.542
24	0.0201	404.0	25.67	20.99	817.7	1.233
25	0.0179	320.4	32.37	33.37	1,031	0.969
26	0.0159	254.1	40.81	53.06	1,300	0.769
27	0.0142	201.5	51.47	84.37	1,639	0.610
28	0.0126	159.8	64.90	134.2	2,067	0.483
29	0.0113	126.7	81.83	213.3	2,607	0.383
30	0.0100	100.5	103.2	339.2	3,287	0.304
31	0.0089	79.70	130.1	539.2	4,145	0.241
32	0.0080	63.21	164.1	857.6	5,227	0.191
33	0.0071	50.13	206.9	1,364	6,591	0.151
34	0.0063	39.75	260.9	2,168	8,310	0.120

Table 300-4-8 DIMENSIONS AND PROPERTIES OF BARE ROUND COPPER MAGNET WIRE -

Continued

			Resistance 20°C (68°F)			
AWG or B&S Type Gage	**Diameter of Bare Wire**	**Area in Circular Mils**	**Ohms per 1,000 feet**	**Ohms per Pound**	**Feet per Pound**	**Pounds per 1,000 feet**
35	0.0056	31.52	329.0	3,448	10,480	0.0954
36	0.0500	25.00	414.8	5,482	13,210	0.0786
37	0.0045	19.83	523.1	8,717	16,660	0.0600
38	0.0040	15.72	659.6	13,860	21,010	0.0475
39	0.0035	12.47	831.8	22,040	26,500	0.0377
40	0.0031	9.888	1,049	35,040	33,410	0.0299
41	0.0028	7.842	1,323	55,740	42,140	0.0237
42	0.0025	6.279	1,668	88,597	53,124	0.0188
43	0.00222	4.932	2,103	140,875	66,988	0.0149
44	0.00198	3.911	2,652	224,000	84,470	0.0118

300-4.10.1.1.2 Round wire may be used if necessary to replace rectangular wire in some types of coils, such as series coils and commutating coils on direct current machines. More winding space is required for round wires if the cross-sectional area of the rectangular wire is to be duplicated. For this reason, round wires cannot always be used to replace rectangular wire wound in restricted spaces such as armature slots of dc machines or stator slots of ac machines. If there is no alternative to using round wire to replace rectangular wire in a motor stator winding, a sample bundle of the proposed round-wire combination should be fitted into a stator slot to insure optimal use of slot area. The circular mil area used should equal the original area as nearly as possible, because reducing the circular mil area of the winding reduces motor capacity. The area of a rectangular wire in circular mils is: Area (circular mils) = 1,275,000 x width (inches) x thickness (inches). For example, a rectangular wire 0.350 inch wide and 0.110 inch thick has an area of 0.35 x 0.110 x 1,275,000 or 49,088 circular mils.

300-4.10.1.1.3 Approximately the same area can be obtained by following combinations: **Round wires in parallel: Total area, circular mils**

3 No. 8	(3 x 16,510 = 49,530)
4 No. 9	(4 x 13,090 = 52,360)
2 No. 8 + 2 No. 11	(2 x 16,510 + 2 x 8,234 = 49,488)

300-4.10.1.2 Insulation Suitability. In addition to the properties required of the insulation in the completed machine, consideration must be given to the conditions to which the windings will be subjected during winding, varnishing, and drying out or baking. All magnet wire should be handled with care in order not to damage the resin film or fibrous covering. All winding equipment should have smooth surfaces with rounded edges and be free of rough spots and burrs that could nick or cut the magnet wire insulation. All coils and windings should be rewound with materials of the same class of insulation (or higher) as the original insulation (see paragraph 300-3.1.3 through 300-3.1.3.1 for definitions of classes). As it is not practical to stock every type and size of magnet wire used in the construction of the original equipment, only the higher temperature types are actually stocked. Appendix A Table 300-A-1 indicates the wires to use for repair work.

300-4.10.1.3 Effect of Insulation Thickness Upon Winding Space. An increase in thickness of the insulation on wire causes an increase in coil size for the same number of turns. This increase is considerable for windings of small size for which the insulation thickness, though small in magnitude, is relatively large compared to the wire diameter.

300-4.10.1.3.1 Table 300-4-9 gives the diameter of the insulation for the M series types of round wire. Table 300-4-10 gives the dimensions for square wire and Table 300-4-11 gives the dimensions for rectangular magnet wire.

300-4.10.1.3.2 The space available for windings in armature and stator slots is limited. It is; therefore, usually desirable to use replacement wire (or wires) which will not have a greater total area than the original wire. The original winding should, however, be inspected for tightness to see if a larger wire area is practical. In order to facilitate production, the factory winding is frequently a loose winding wedged in place. Hand winding will often permit a tighter winding to be installed without difficulty.

300-4.10.1.3.3 In spool type coils, such as used for contactor coils or shunt field coils of dc machines, the height of the coil is usually limited by the spool or core on which it is wound. Any change in dimensions will be in the thickness of the coil. For the same number of turns, the following relation holds approximately:

$$\frac{tr}{to} = \frac{Ar}{Ao}$$

where tr and to are the thickness of the rewound and original coils, respectively; Ao is the total area of copper and insulation for the original wire; and Ar is the total area of copper and insulation for the replacement wire, or, if several wires are used to replace one wire, the sum of the total areas of the replacement wires. Observation of the space available for the coil in the machine will show whether an increase in coil size can be tolerated.

300-4.10.1.4 Effect of Insulation Thickness Upon Coil Performance. The magnetic characteristics of coils in ac motors and equipment are primarily dependent upon the total number of turns in the coil and are practically unaffected by small changes in resistance. Such coils should be rewound with the same number of turns using any available wire (or wires) with ample conductor cross-section to carry the current and insulation suitable for the application. The magnetic characteristics of dc coils depend upon the number of turns and also upon the coil resistance since this determines the coil current. If the insulation thickness is increased, the coil thickness, average length per turn, total length, and the coil resistance will be greater for the same number of turns. Consequently the current will be less when the coil is used on the same voltage, and its magnetic characteristics will be different. Direct current coils can usually be rewound with wire of the same conductor area but different insulation thickness and different total area if compensating changes are made in the coil.

300-4.10.1.4.1 One such change is to alter the number of turns as follows:

$$\frac{Nr}{No} = \frac{Ao}{Ar}$$

where Nr and No are the number of turns in the rewound and original coils, respectively; Ao is the total area of copper and insulation for the original wire; and Ar is the total area of copper and insulation for the replacement wire, or, if several wires are used to replace one wire, the sum of the total areas of the replacement wires. This method produces a coil of substantially the same dimensions as the original coil. This method of compensation is suitable only for coils which are not connected in series with other similar coils or with resistors. However, if all coils in a series group are rewound in the same way, the magnetic characteristics will be preserved. The rewound coil will run hotter, however, if the replacement wire has a much larger total area than the original wire. For example, consider four shunt field coils connected in series across a 120-volt line. The original and replacement windings nominal calculations are depicted in Table 300-4-12. Since the coils have the same dimensions, and the same ampere turns, their magnetic characteristics will be the same, but there is more heat developed in the rewound coil and it will run hotter.

300-4.10.1.4.2 Another method of compensating for wire insulation is padding the inside of the coil to build up the mean length of turn to that of the original coil. This method is obviously applicable only when the diameter of the insulation of the replacement wire is smaller than for the original wire. Measure the thickness of the original coil and compute the thickness of the rewound coil by the formula in paragraph 300-4.10.1.3.3. The pad for the coil should be made equal in thickness to 1/2 the difference between the thicknesses of the two coils. This keeps the center of the coil at the same distance from the coil axis as in the original coil. The average length of turn is unchanged, as are the coil resistance, coil current, ampere turns, and heat development. This method can be used for rewinding even when only one of a set of shunt field coils is to be changed.

Table 300-4-9 DIMENSIONS OF ROUND FILM COATED MAGNET WIRE

				Single (M)		Heavy (M2)		Triple (M3)		
AWG Size	Bare Wire Diameter (in)			Minimum Increase in Diameter (in)	Maximum Overall Diameter (in)	Minimum Increase in Diameter (in)	Maximum Overall Diameter (in)	Minimum Increase in Diameter (in)	Maximum Overall Diam-eter (in)	AWG Size
	Mini-mum	Nominal	Maxi-mum							
4	0.2023	0.2043	0.2053	-	-	0.0037	0.2908	-	-	4
5	0.1801	0.1819	0.1828	-	-	0.0036	-	-	-	5
6	0.1604	0.1620	0.1628	-	-	0.0035	0.1671	-	-	6
7	0.1429	0.1443	0.1450	-	-	0.0034	0.1491	-	-	7
8	0.1272	0.1285	0.1295	-	-	0.0033	0.1332	-	-	8
9	0.1133	0.1144	0.1150	-	-	0.0032	0.1189	-	-	9
10	0.1009	0.1019	0.1024	-	-	0.0031	0.1061	-	-	10
11	0.0898	0.0907	0.0912	-	-	0.0030	0.0948	-	-	11
12	0.0800	0.0808	0.0812	-	-	0.0029	0.0847	-	-	12
13	0.0713	0.0720	0.0724	-	-	0.0028	0.0757	-	-	13
14	0.0635	0.0641	0.0644	0.0016	0.0666	0.0032	0.0682	0.0048	0.0700	14
15	0.0565	0.0571	-	0.0015	0.0594	0.0030	0.0609	0.0045	0.0627	15
16	0.0503	0.0508	0.0511	0.0014	0.0531	0.0029	0.0545	0.0043	0.0562	16
17	0.0448	0.0453	0.0455	0.0014	0.0475	0.0028	0.0488	0.0041	0.0504	17
18	0.0399	0.0403	0.0405	0.0013	0.0424	0.0026	0.0437	0.0039	0.0452	18
19	0.0355	0.0359	0.0361	0.0012	0.0379	0.0025	0.0391	0.0037	0.0406	19
20	0.0317	0.0320	0.0322	0.0012	0.0339	0.0023	0.0351	0.0035	0.0364	20
21	0.0282	0.0285	0.0286	0.0011	0.0303	0.0022	0.0314	0.0033	0.0326	21
22	0.0250	0.0253	0.0254	0.0011	0.0270	0.0021	0.0281	0.0032	0.0293	22
23	0.0224	0.0226	0.0227	0.0010	0.0243	0.0020	0.0253	0.0030	0.264	23
24	0.0199	0.0201	0.0202	0.0010	0.0217	0.0019	0.0227	0.0029	0.238	24
25	0.0177	0.0179	0.0180	0.0009	0.0194	0.0018	0.0203	0.0027	0.0214	25
26	0.0157	0.0159	0.0160	0.0009	0.0173	0.0017	0.0182	0.0026	0.0193	26
27	0.0141	0.0142	0.0143	0.0008	0.0156	0.0016	0.0164	0.0024	0.0173	27
28	0.0125	0.0126	0.0127	0.0008	0.0140	0.0016	0.0147	0.0023	0.0156	28
29	0.0112	0.0113	0.0114	0.0007	0.0112	0.0015	0.0133	0.0022	0.0142	29
30	0.0099	0.0100	0.0101	0.0007	0.0112	0.0014	0.0119	0.0021	0.0128	30
31	0.0088	0.0089	0.0090	0.0006	0.0100	0.0013	0.0108	-	-	31
32	0.0079	0.0080	0.0081	0.0006	0.0091	0.0012	0.0098	-	-	32
33	0.0070	0.0071	0.0072	0.0005	0.0081	0.0011	0.0088	-	-	33
34	0.0062	0.0063	0.0064	0.0005	0.0072	0.0010	0.0078	-	-	34
35	0.0055	0.0056	0.0057	0.0004	0.0064	0.0009	0.0070	-	-	35

Table 300-4-9 DIMENSIONS OF ROUND FILM COATED MAGNET WIRE - Continued

				Single (M)		Heavy (M2)		Triple (M3)		
AWG Size	Bare Wire Diameter (in)			Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	AWG Size
	Mini-mum	Nominal	Maxi-mum	Increase in Diameter (in)	Overall Diameter (in)	Increase in Diameter (in)	Overall Diameter (in)	Increase in Diameter (in)	Overall Diam-eter (in)	
36	0.0049	0.0050	0.0051	0.0004	0.0058	0.0008	0.0063	-	-	36
37	0.0044	0.0045	0.0046	0.0003	0.0052	0.0008	0.0057	-	-	37
38	0.0039	0.0040	0.0041	0.0003	0.0047	0.0007	0.0051	-	-	38
39	0.0034	0.0035	0.0036	0.0002	0.0041	0.0006	0.0045	-	-	39
40	0.0030	0.0031	0.0032	0.0002	0.0037	0.0006	0.0040	-	-	40
41	0.0027	0.0028	0.0029	0.0002	0.0033	0.0005	0.0036	-	-	41
42	0.0024	0.0025	0.0026	0.0002	0.0030	0.0004	0.0032	-	-	42
43	0.0021	0.0022	0.0023	0.0002	0.0026	0.0004	0.0029	-	-	43
44	0.0019	0.0020	0.0021	0.0001	0.0024	0.0004	0.0027	-	-	44

Table 300-4-10 DIMENSIONS OF SQUARE FILM COATED MAGNET WIRE

				Heavy (M2)		Quadruple (M4)		Film/Glass(M2Dg2)		
AWG Size	Bare Wire Diameter (in)			Minimum	Maxi- mum	Minimum	Maxi- mum	Minimum	Maxi- mum	AWG Size
	Mini- mum	Nominal	Maxi- mum	Increase in Diameter (in)	Overall Diam- eter (in)	Increase in Diameter (in)	Overall Diam- eter (in)	Increase in Diameter (in)	Overall Diameter (in)	
0	0.3219	0.3249	0.3279	0.0030	0.3329	0.0050	0.3349	0.016	0.351	0
1	0.2864	0.2893	0.2922	0.0030	0.2972	0.0050	0.2992	0.015	0.314	1
2	0.2550	0.2576	0.2602	0.0030	0.2652	0.0050	0.2673	0.015	0.282	2
3	0.2271	0.2294	0.2317	0.0030	0.2367	0.0050	0.2387	0.014	0.253	3
4	0.2023	0.2043	0.2063	0.0030	0.2113	0.0050	0.2133	0.014	0.227	4
5	0.1801	0.1819	0.1837	0.0030	0.1887	0.0050	0.1907	0.014	0.204	5
6	0.1604	0.1620	0.1636	0.0030	0.1686	0.0050	0.1706	0.014	0.184	6
7	0.1429	0.1443	0.1457	0.0030	0.1507	0.0050	0.1527	0.013	0.165	7
8	0.1272	0.1285	0.1298	0.0030	0.1348	0.0050	0.1368	0.013	0.149	8
9	0.1133	0.1144	0.1155	0.0030	0.1205	0.0050	0.1225	0.012	0.134	9
10	0.1009	0.1019	0.1029	0.0030	0.1079	0.0050	0.1099	0.012	0.121	10
11	0.0897	0.0907	0.0917	0.0030	0.0967	0.0050	0.0987	0.011	0.099	11
12	0.0798	0.0808	0.0818	0.0030	0.0868	0.0050	0.0888	0.011	0.099	12
13	0.0710	0.0720	0.0730	0.0030	0.0780	0.0050	0.0800	0.011	0.090	13
14	0.0631	0.0641	0.0651	0.0030	0.0701	0.0050	0.0721	0.011	0.082	14

Table 300-4-11 DIMENSIONS OF RECTANGULAR MAGNET WIRE

	Bare Width (in)									
Bare Thickness (in)	**0.063**	**0.079**	**0.098**	**0.124**	**0.157**	**0.197**	**0.248**	**0.315**	**0.394**	**0.492**
0.031	1	1	1	1	1	1	1	1	1	1
0.039	1	1	1	1	1	1	1	1	1	1
0.049	1	1	1	1	1	1	1	1	1	1
0.063		1	1	1	1	1	1	1	1	1
0.079			2	2	2	4	4	4	4	4
0.098				3	3	4	4	4	4	4
0.124					3	4	4	4	4	4
0.157						4	4	4	4	4
0.197							5	5	5	5
0.248								5	5	

NOTES:
1. Available in heavy (M2), quadruple (M4) types with rounded edges.
2. Available in heavy (M2), quadruple (M4) types with 0.020 radius corners.
3. Available in heavy (M2), quadruple (M4) types with 0.025 radius corners.
4. Available in heavy (M2), quadruple (M4) types with 0.031 radius corners.
5. Available in heavy (M2), quadruple (M4) types with 0.039 radius corners.
6. Increase dimensions for heavy (M2) is 0.0030 and 0.0050 for quadruple (M4).

Table 300-4-12 ORIGINAL AND REWOUND COIL DATA

	Original Winding No. 30, Type M	**Replacement Winding No. 30, Type M3**
Total area of wire, copper, plus insulation circular mils	121	171
Number of turns[1]	1,000	$1{,}000 \times \frac{121}{171} = 708$
Average length per turn, feet	1	1
Total length, feet	1,000	708
Resistance, ohms per 1,000 feet at 25° C	105	105
Total resistance, ohms	105	74.3
Voltage drop across coil	30	30
Current, amperes	0.286	0.404
Ampere turns	286	286
Heat developed in coil, watts	8.6	12.1
[1] See equation, $N_r / N_0 = A_0 / A_r$		

SECTION 5.

RECONDITIONING ELECTRICAL EQUIPMENT AFTER CONTAMINATION BY SEAWATER, LITHIUM BROMIDE, OIL, CARBON DUST OR A COMBINATION OF THESE MATERIALS

300-5.1 GENERAL

300-5.1.1 IMPORTANCE OF THOROUGH RECONDITIONING. Electrical equipment may be damaged by being submerged in or splashed with seawater. Since reliability is imperative in electrical equipment, such equipment should be restored as nearly as possible to new machine condition. Much experience has been accumulated on reconditioning electrical equipment that has been damaged by seawater. This experience shows conclusively that the work shall be done thoroughly to minimize the possibility of subsequent failure. If electrical equipment has been submerged in seawater, all coils and windings should be replaced to obtain maximum reliability; also all laminated steel magnet core structures should be replaced. Salt removal from these components is practically impossible. Electrical equipment may also be damaged by spilling or splashing lithium bromide onto the coils or cores of the equipment. Lithium bromide is a salt and may cause either electrical winding system failure or laminated steel magnet core failure of equipment using standard insulation systems. Equipments using sealed insulation systems described in paragraph 300-4.5.8.8 are not similarly affected by lithium bromide contamination. As with seawater damaged equipment, maximum reliability of lithium bromide damaged equipment with standard insulation systems is obtained with replacement of all windings, coils and laminated core structures as described in paragraph 300-5.4. Procedures for reconditioning electrical equipment damaged by lithium bromide are described in paragraph 300-5.7.

300-5.1.2 SCOPE OF THIS SECTION. This section covers successful reconditioning methods. This includes preliminary rust preventive measures, and cleaning and drying, all of which form important parts of the reconditioning procedure, and detailed instructions for permanent and temporary reconditioning. For reconditioning of certain electrical equipment by use of an ultrasonic cleaning tank, see **NSTM Chapter 631, Preservation of Ships In Service.**

CAUTION

Ultrasonic cleaning to recondition motors, motor generators, and wound components has generally been ineffective in removing dirt and contaminants from slot sections and surfaces not directly exposed to ultrasonic waves.

300-5.1.3 PRELIMINARY RUST PREVENTIVE MEASURES. In cases where electrical equipment cannot be completely disassembled, cleaned, and dried immediately upon removal from submersion, it should receive temporary treatment to prevent damage from rust and corrosion. This should consist of removing as much seawater as possible and applying rust preventive compound to metallic surfaces. This treatment is extremely important since rust can greatly increase the time, work, and material required for reconditioning. Success or failure in preventing extensive corrosion depends upon immediate action after removal from saltwater.

300-5.1.3.1 Rust Preventive Compound Not Available. In case rust preventive compound is not available, the equipment should be left completely submerged until prompt rust prevention methods can be employed. Partial or intermittent submergence in and removal from saltwater without treatment to prevent rust, usually results in more damage than occurs during complete submersion.

300-5.1.3.2 Where Disassembly Is Not Practical. If possible, equipment should be immediately dismantled to permit cleaning and rust preventive treatment of the component parts. Where disassembly is not practical, the treatment should be as thorough as possible. If freshwater is available, the equipment should first be washed either by the use of a hose or by submersion. Equipment that has been submerged in or splashed with saltwater should be cleaned by flushing with freshwater. The effluent from each flushing step should be tested for salinity until the final flushing sequence yields a reading of freshwater. After washing, all accessible parts should be wiped dry. If available, compressed air may be used as an aid in drying. If applied to insulation which is to be reconditioned, air pressure should be limited to a value which will not mechanically damage the insulation. A pressure of 30 lb/in^2 will usually be satisfactory but this will depend upon the type and condition of the insulation. Compressed air should be free of abrasive particles which may damage insulation.

300-5.1.3.3 Rust Preventive Use. After drying as much as possible, a suitable compound such as MIL-C-16173 compound, rust preventive, grade 3, thin film, (polar type) (NSN 8030-00-244-1296, 1 gallon; 8030-00-244-1293, 5 gallons; 8030-00-244-1294, 55 gallons) should be applied to all metallic parts which are susceptible to corrosion. This compound may be applied with a cloth, brush, or spray. The compound classified as grade 3 should be used. This compound displaces water and prevents rust. Its flashpoint is not less than 100°C. It has no ill effects on the skin but may produce dizziness if proper ventilation is not provided. It may have a corrosive effect on paint and varnish and leave tape and fabric insulation soggy and sticky. It shall not be applied to insulation which is to be replaced. It should be liberally applied to bearing surfaces, journals, and unpainted metallic working surfaces. Where machines have forced lubrication, it may be possible to circulate the compound through the system. If practical, the rotors should be turned over slowly as the compound is forced through the bearings. The treatment should continue until the compound has reached all parts which might rust.

300-5.2 CLEANING

300-5.2.1 PRELIMINARY STEPS. After disassembly for inspection and determination of the measures to be employed in reconditioning, cleaning operations should be initiated on equipment which have been subjected to fuel or lubrication oil, contaminated water, and so forth. In order to facilitate cleaning, disassembly should be as complete as possible and parts which are to be replaced should be removed. Numerous materials and solvents are available for removing grease, oil, and other foreign deposits but it is important that the properties, characteristics, and limitation of each be known. Certain solvents readily remove grease and oil but may injure varnish and impregnating compounds. Others are flammable and explosive under certain conditions or may produce toxic effects on persons exposed to the fumes.

300-5.2.2 CLEANING BY MEANS OF COMPOUNDS AND WATER. Only the following compounds should be used for cleaning electrical equipment:

CAUTION

Nonmagnetic rotor coil retaining rings of certain MnCr alloys become susceptible to stress corrosion cracking in the presence of moisture. These rings are used on two pole (3,600 rpm) cylindrical rotor ship service generator sets. Water cleaning of the rotor for all such units shall not be performed. These units are to be cleaned using nonwater based techniques. If the rotors have been submerged, then the retaining rings shall be removed, cleaned, dried, and dye penetrant tested to verify the absence of cracks or pits. All cracks and pits shall be completely removed before the retaining ring is reused.

a. Cleaning compound P-D-220 (NSN 7930-00-249-8036) or nonionic type detergent according to MIL-D-16791 (NSN 7930-01-055-6121 [qty. 1 gal] or NSN 7930-00-282-9700 [qty. 55 gals]) may be used. Both types should be mixed in a proportion of 1 pound to 2-1/4 gallons of water, and can be used on insulation which is to be reconditioned. After the cleaning is completed, all surfaces should be thoroughly washed with fresh water to remove the alkali.

b. Powdered saltwater soap (synthetic detergent), MIL-D-12182 (NSN 7930-00-252-6797) may be used in soft or hard water and should be mixed in a proportion of 1 pound to 50 gallons of water. This compound has the advantage of being neutral; it is neither acid nor alkaline, and can be used to clean insulation which is to be reconditioned.

c. Dishwashing compound, P-D-425, (NSN 7930-00-267-49 32), should be mixed in a proportion of 1 pound to 25-gallons of water. This solution may be injurious to the skin and proper precautions such as the use of rubber gloves should be taken. All traces of alkali should be removed with fresh water after the cleaning has been completed. This cleaning solution should not be used on insulation which is to be reconditioned.

d. Steam cleaning compound can be used for cleaning armatures which do not respond satisfactorily to treatment by solvents. Steam cleaning compound (NSN 6850-00-965-2087, 25-pound drum; 6850-00-965-2329, 400-pound drum) and butyl alcohol are added to water in the proportions of 15 to 20 pounds of steam cleaning compound and 1 quart of butyl alcohol to 1,000-gallons of water. The armature to be cleaned is placed in the solution with its axis vertical and the commutator end up. The solution is held at a constant temperature of 88°C (190°F), and stirred by an air agitator to circulate it through the windings and out through the commutator risers. Cleaning requires 8 to 10 hours depending on the condition of the armature. For detailed information see **NSTM Chapter 235, Electric Propulsion Installations.**

e. Cantol Tech 736 is useful in removing oil and carbon dust from the windings of motors and motor generators without damaging the insulation system. It is a water-based alkaline cleaner produced by Cantol, Inc. The solution is a clear light green liquid with a mild odor and a relatively high boiling point of 98°C (210° F). It is easily rinsed with water and is safe for use with most insulation systems. Dilute in hot water in accordance with manufacturer's recommendations. Avoid contact with eyes and wear safety glasses and rubber gloves under conditions of continuous use, ensure adequate ventilation is provided to minimize exposure to the vapor mist produced when used with a high pressure sprayer.

f. Formula 409, a water based all purpose cleaner produced by Clorox Company is useful in the removal of oil and carbon dust from the windings of motors and motor generators. This solution is a clear green liquid with a mild odor and is not flammable. It is easily rinsed with water and safe for most insulation systems when exposed for a short period of time (less than 8 hours). Formula 409 produces little or no toxic vapors; however, the use of safety glasses and rubber gloves are recommended. Ensure adequate ventilation is provided to minimize exposure to the vapor mist produced when used in a high pressure sprayer.

300-5.2.2.1 Steam or Hot Water Cleaning. For steam or hot water cleaning, the use of a steam spray machine, such as a steam jenny may be useful. Portable units may be used which generate steam electrically and project a pressure spray of hot cleaning solution and detergent through hose and nozzle. Live steam should not impinge directly on the windings. To avoid damage to insulation the temperature of the cleaning solution impinging on the windings should not exceed 90°C (194°F) and the pressure at the windings should not exceed 30 lb/in^2 . After any cleaning operation where water is used, the surface moisture should be removed with a clean cloth and the insulation dried promptly to keep the amount of water which soaks into the insulation as low as possible.

300-5.2.3 CLEANING ELECTRICAL EQUIPMENT BY MEANS OF SOLVENTS. The use of solvents for cleaning should be avoided insofar as practicable because of their corrosive action, their injurious effect on various insulating materials, the fire risk, and especially because of their toxicity. The choice of a solvent will depend upon the instructions in this chapter, the instructions on the solvent label, the fire risk involved, and the facilities for maintaining adequate ventilation.

300-5.2.3.1 Prohibitive Solvents and Alcohol Use. Gasoline, benzene, petroleum ether, carbon tetrachloride or trichloroethylene must not be used for cleaning under any circumstances. See **NSTM Chapter 670, Stowage, Handling, and Disposal of Hazardous General Use Consumables.** Inhibited methyl chloroform (1,1,1 trichloroethane), O-T-620, or any compound thereof, is an ozone depleting substance and must not be used. Isolpropyl alcohol will injure some types of insulating varnishes and care should be taken when using alcohol for cleaning electrical equipment. Alcohol, if used, should be isopropyl (NSN 6810-00-227-0410). It is flammable and should not be used on energized equipment or in the vicinity of equipment subject to sparking.

300-5.2.3.2 Dry Cleaning Solvent. Dry cleaning solvent, type II, P-D-680, (NSN 6850-00-274-5421) requires observance of precautions against fire and explosion. The efficiency of this solvent will be somewhat less than that of the chlorinated solvents but ill effects to personnel will also be reduced. Experience has shown that this solution has an injurious effect upon some types of insulation. Before using it, a test should be made by applying the solution to a small spot on the insulation concerned to determine whether it is affected by the solvent.

300-5.2.3.3 Precautions. During the use of any solvent the following precautions shall be observed:

a. Guard carefully against fire.

b. Use vapor-proof or watertight portable lights if supplementary lighting is required.

c. Have fire extinguishers available for immediate use.

d. Prevent possible sparks caused by one metallic object striking another.

e. If a spray or atomizer is used, ground the nozzle.

f. Avoid saturation of operator's clothing with solvent. Wear impervious (solvent-resistant) gloves to avoid contact with the skin. Wear appropriate eye/face protective devices when splash hazard exists (e.g., pouring solvent).

g. Provide adequate ventilation (exhaust fans or other suitable means).

h. Use of solvent in closed or very confined spaces, where ventilation is lacking and for some reason cannot be provided, requires use of full-face air supply respirator and related controls (refer to damage control procedures involving use of buddy system and lifelines).

i. Where normal (comfort) ventilation is present and very small volumes are used (few ounces, at most), the minimum requirement is the proper use of an approved organic vapor (charcoal) respirator. The procedure should be studied to minimize exposure to the user, adjacent spaces, and nearby personnel.

j. Where larger volumes are used indoors (many ounces, quarts, gallons), the use of specially applied exhaust ventilation and full-face air supply respirators, or equivalent respiratory protection, are recommended.

k. Where portable exhaust ventilation is applied, the exhaust face (intake end of the flexible duct system) must be placed near the operation for best capture of the fumes. The direction of ventilation should be checked, to assure that fumes are being exhausted from the space and that the exhausted air is discharged topside away from personnel and openings to prevent recirculation of fumes into other occupied interior spaces.

l. Do not apply on hot equipment or use in the presence of open flames.

m. Ensure that solvents are properly labeled as to hazard and stored properly (in accordance with FED-STD-313) and that adequate marking/labeling is carried over onto any subdivisions or transfer of material into other containers.

NOTE

Where exhaust to the atmosphere is unavoidable, the requirements and restrictions of 300-4.5.7.10.a.6 and 300-4.5.7.10.a.7 shall be observed.

300-5.2.3.4 Application of Cleaning Solvents. The method of application is dependent upon the characteristics of the solvent. When handwiping, the method for applying solvents listed in paragraphs 300-5.2.3 through 300-5.2.3.2 is by means of a lintless cloth moistened with fluid. Solvent containers shall be recapped after each application of the fluid. Immersion of mechanical parts in a solvent is approved if the solvent containers are covered preventing the concentration of fumes from exceeding safe levels. The requirements of paragraph 300-5.2.3.3 apply (see item j). Solvent cleaning of mechanical parts may also be performed topside or in a compartment especially equipped to exhaust heavy concentrations of fumes. Solvent spraying should only be performed as part of a reconditioning procedure (see paragraph 300-4.5.7.10). Atomized solvents may be toxic. The safety requirements of paragraph 300-5.2.3.3 are applicable. Obstinate foreign materials may be removed with a scraper or scrubbed off with a brush. After the apparatus is cleaned, it should be dried thoroughly by wiping and if necessary by applying compressed air until all traces of the solvent have been removed. If compressed air is applied to insulation being reconditioned, the air pressure should not exceed 30 lb/in^2 and the air should be filtered and dry.

300-5.2.4 REMOVAL OF RUST. In addition to the elimination of grease, oil, or other foreign material from the surfaces of mechanical parts, all rust should be removed. On nonworking surfaces this may be done by means of a scraper, emery cloth, wire brush, portable buffer, sand blasting, or other convenient means. On fitted surfaces all traces of rust should be removed by means of a fine stone or nonmetallic abrasive cloth. After rust removal, further corrosion of unpainted metallic surfaces which might occur during the reconditioning period may be prevented by applying grade 2 compound, rust-preventive, thin-film (polar-type), MIL-C-16173 (paragraph 300-5.1.3.3).

300-5.2.5 REMOVAL OF SALT. The principal salt found in seawater is sodium chloride. In addition, magnesium chloride and calcium chloride are present in lesser amounts. Since these salts have a corrosive effect on metals, it is important that all traces of seawater and salt deposits be thoroughly removed before restoring the equipment to service. If not removed salt deposits will absorb water and cause continued corrosion. This may eventually result in failure of rotating parts such as the teeth on core laminations of rotors, or, if the corrosion occurs in proximity to insulation, failure may occur. It is very important that salts be thoroughly removed as soon as possible to prevent damage from corrosion.

300-5.2.5.1 Freshwater Washing. After disassembling as completely as possible, the parts should be thoroughly washed with freshwater. In certain localities, supposedly freshwater may be brackish and unless it is known that the salt content is insignificant, the water used for washing should be given a salinity test. Where salt content is appreciable, provisions shall be made for removing the salt or the equipment shall be moved to a point where freshwater is available to complete the washing operation. The temperature of the water has little effect on the solubility of the salts but hot water will be more effective in removing oily or greasy deposits. If possible, the equipment should be immersed in freshwater which is constantly being changed by continuous flow and allowed to soak for several hours. Where a continuous flow of water is not available, the water should be changed frequently. If immersion is impractical, as may be the case when large machines are involved, the freshwater may be applied with a hose. Care must be taken to avoid damage to insulation which is not being renewed. Usually no damage results if the water pressure does not exceed 25 lb/in^2 .

300-5.2.5.2 Salt Content Test. As washing progresses, drippings from the equipment should be tested for salt content. This may be done with a standard salinity test set carried aboard ship for determining the salt content of boiler feed water. In case such a test set is not available, the following method may be used. Place approximately 2 ounces of drip water from the equipment into a container of convenient size. Add two or three drops of dilute nitric acid followed by two drops of silver nitrate. If salt is present, the mixture will become clouded, the degree of clouding indicating the salt content. Washing should be continued for at least 1 hour after the salinity test shows that the salt has been removed. This may require several hours or even days of washing, depending upon size and construction of the equipment.

300-5.2.5.3 Insulation Test. In addition to the salinity test, equipment exposed to seawater should be tested, after drying, in accordance with paragraph 300-5.3.8 to obtain another check on the completeness of salt removal.

300-5.3 DRYING

300-5.3.1 GENERAL. Drying insulation is a necessary step in some procedures for reconditioning electrical equipment which has been submerged in or splashed with water. It may also be necessary at times to dry equipment which has not been submerged in or splashed with water, but which has absorbed moisture from the air as a consequence of having stood idle for a considerable period of time. The best method to follow in each specific case depends upon local conditions and the facilities and equipment available.

300-5.3.1.1 Heating Methods. In general, heat and the circulation of dry air or the application of a vacuum are necessary to remove moisture from insulation. Heat may be provided by either of two methods or by a combination of both. One method is by external application. The second method is by circulating current at low voltage through the conductors to provide necessary heat. The second method should not be employed for drying water-soaked insulation until it has been partially dried by the first method.

300-5.3.1.2 Temperature Monitoring. Whichever heating method is used, insulation temperature must be closely checked. This may be done by means of temperature detectors, permanently or temporarily installed, or by thermometers placed so that they may be easily read at the hottest spots on the equipment. Heat application should be steady. Interruption in heating to the extent that the apparatus approaches ambient temperature may allow moisture to condense on the insulation and retard drying. Drying cannot be hurried; many hours, or even days, may be needed for satisfactory results. Fire risks shall be avoided and positive air circulation provided. Ventilation ample for moisture escape is essential to, and hastens, drying. Insulation cannot be dried by continuous application of heat in an enclosure filled with moisture-saturated air.

300-5.3.2 OVEN DRYING. Small equipment which can be moved can be dried in existing baking ovens or drying kilns, or a room or enclosure may be temporarily arranged and equipped for drying. The oven of a cooking range may be used for meters, relays, and other small parts.

300-5.3.2.1 Temporary Oven. If no existing ovens are available for drying equipment, a temporary oven can be constructed. Numerous materials (such as heat-insulated panels secured to suitable frames, sheet-iron, brick, or concrete blocks lined with some form of insulation) are available for this purpose. Such an oven can be built around large equipment that cannot be moved and, in the case of enclosed machines, the enclosure itself may serve as an oven. A canvas or tarpaulin cover may be used to enclose open machines if due care is exercised to see that heating equipment cannot set fire to the cover.

300-5.3.2.2 Heating Sources. Electric heaters, steam coils, radiators, stoves, or hot air furnaces can be used to supply heat. If steam is used, see that there are no leaks which might introduce moisture into the enclosure. The use of open flame heaters is not recommended. The dust, soot, and gases from them usually prohibit their use.

300-5.3.2.3 Oven Controls. There are three important points to be remembered when drying insulation in an oven. These are:

a. The temperature must not be so high that it causes the formation of steam in voids in the insulation and results in rupture and permanent injury. The danger from this, however, is not as great as might be expected, because heat is applied from the outside and a large amount of heat is absorbed by water before it turns to steam. With a reasonable amount of ventilation, heat will be carried off before excessive pressures are developed in the insulation.

b. The oven air temperature should not exceed 300°F (149°C) when drying any class of insulation. The oven air temperature should be maintained at 300° - 20°F (149° - 11°C) until the winding reaches a temperature of 220° + 10°F (104° + 6°C). The oven air temperature should then be adjusted to maintain the winding temperature at 220° + 10°F (104° + 6°C) until the winding is dry (refer to paragraph 300-5.3.7). In an emergency, equipment may be urgently needed, and there is a strong temptation to obtain quicker results by using higher temperatures. In certain cases, higher temperatures have been used, and the insulation successfully restored to service. However, as temperature is allowed to go up, the risk of permanently injuring insulation also increases.

c. Provision must be made for removing moisture from the oven. This may be done by providing openings which allow circulation of air by convection. More thorough removal of moisture can be accomplished by forced ventilation by means of fans or blowers. The fresh, dry air which enters the enclosure should first pass over the heaters to become heated, and should then circulate over the insulation that is being dried.

300-5.3.2.4 Winding Inspection. The windings should be inspected during drying and the temperature lowered if there is any sign of compound running out of the coils. The softening point of different compounds may vary considerably.

300-5.3.2.5 Rotation of Machines. If a machine can be rotated as it is dried, the process may be accelerated. If it cannot be rotated continuously, frequent turning of the rotor 180 degrees is worthwhile. Changing the position of any apparatus may permit the escape of trapped water. Current transformers have been dried until they showed infinite insulation resistance; yet, upon removing them from the oven, a cup of water has run out. Compensators have shown infinite readings; yet, when restored to service they have failed because of the presence of water which has not been removed.

300-5.3.2.6 Trapped Water. Equipment that is hot at the time submersion occurs may be particularly difficult to dry. As the machine cools off following submersion, vacuums are created in tiny pockets and water will enter joints which are so small that it is difficult to force the water back out again during drying. This is particularly true of large machines which operate at high temperatures.

300-5.3.3 VACUUM DRYING. It is not always easy to drive moisture out of fibrous insulation, even at 100°C (212°F). If facilities are available, the quickest and most effective method is by means of combined heat and vacuum. In some instances it has been impossible to recondition certain types of apparatus by any other method. If apparatus to be dried is heated to the boiling point of water, in a vacuum, the moisture is usually completely removed. For optimum results, water should be vaporized because under some conditions and with certain materials capillary force may approximate 15 lb/in^2 . Therefore good vacuum alone may not be able to overcome the capillary action. The boiling point of water is reduced as vacuum is increased. Therefore, materially lower temperatures may be used for removing water in a vacuum as compared with atmospheric pressure. Temperatures less than 100°C (212°F) allow very rapid evaporation of moisture and thorough drying in a moderately good vacuum.

300-5.3.3.1 Temperature Effect. If the temperature is raised much above the boiling point, internal pressures may be created which may result in injury to the insulation. It is important, therefore, that the temperature be raised slowly and be carefully controlled. The temperature of the insulation should not exceed the boiling point of water, at the particular vacuum existing, by more than 10°F.

300-5.3.3.2 When Vacuum Drying Is Complete. When no further water comes out at a given vacuum, increasing the vacuum will result in more water being driven off and the temperature in the apparatus will decrease due to the increased evaporation of water. Drying should be continued at the maximum vacuum obtainable until no further water is driven off. The vacuum should then be gradually reduced with corresponding increase in temperature until atmospheric pressure is reached. If insulation resistance measurements then show that no further drying is required, the equipment is ready for any other reconditioning which may be necessary.

300-5.3.3.3 Accelerated Drying. If conditions permit, drying in a vacuum may be accelerated if the vacuum is broken at intervals and clean dry air is allowed to enter the tank. In this way the new air permeates the windings, takes up moisture, and is then removed.

300-5.3.3.4 Temporary Tanks. In cases where permanent vacuum tanks do not exist, various methods have been used to construct a temporary tank. If large amounts of equipment are involved, the construction of a vacuum tank will be justified. In one instance a tank was improvised by equipping a 10-foot length of 36-inch cast iron pipe with headers, wrapping strip heaters on the outside of the pipe, and covering this with insulating material.

In another case, a tank was constructed of plate steel, welded, and properly reinforced.A length of 1-inch garden hose served as a gasket between the tank and cover. Strip heaters inside the tank provided heat, a trap served to catch oil and water, and a portable pump gave vacuum values up to 29 inches of mercury.

300-5.3.3.5 Use of Steam Ejectors. Steam ejectors also provide a reliable method of producing a vacuum. The apparatus for producing heat may be either inside or outside the tank depending upon which is more convenient. If possible, it is desirable to subject the equipment to a preliminary drying and have it up to the required temperature before it is placed in the vacuum tank.

300-5.3.3.6 Instrumentation and Measurement Option Through Tanks. Spark plugs in the shell or the heads of the vacuum tank may be used for bringing out temperature detector leads and also leads from the winding for measuring insulation resistance, or for determining temperature by hot resistance, without opening the tank.

300-5.3.4 DRYING WITH ELECTRIC HEATERS. Where a source of electric power is available, grids or strip heaters provide a most satisfactory means of producing heat in an oven, vacuum tank, or in individual large machines. They are easily located in any desired position and the amount of heat can readily be controlled.

300-5.3.4.1 Heater Capacity. The capacity required in the heaters will vary with the amount of equipment to be dried, degree of enclosure, and amount of ventilation. It is, therefore, impossible to give a rigid rule for determining the exact size heater required. An estimate, however, may be made as follows: The approximate weight of the apparatus to be dried should first be calculated on the assumption that it consists entirely of steel weighing 485 pounds per cubic foot. The quantity of energy required to cause an increase in temperature of the material may be found by substituting in the following formula:

$$\text{Kilowatt hours} = \frac{3.5 \text{ x wt. in lbs x } {}^\circ\text{F rise}}{100{,}000}$$

300-5.3.4.1.1 For example, assume that a machine weighing 10,000 pounds is to be dried at 200°F. If the ambient temperature is 75°F, an increase of 125°F will be required. The amount of energy necessary to produce this increase in temperature will be 3.5 x 10,000 x 125/100,000 = 43.75 kilowatt hours. The rate of increase in temperature should not exceed about 7°F per hour; 125°F rise will, therefore, require 18 hours, 43.8 kilowatt hours divided by 18 equals 2.4 kilowatts required to increase the temperature of 10,000 pounds of steel 125°F in 18 hours. This is based on the assumption that no heat is lost by radiation or by forced or natural convection. The kilowatt capacity thus calculated may be increased to some extent, say to 3.5 or 4.0 kilowatts, to allow for heat loss. If precautions are taken against heat loss and the fresh air admitted to the machine is limited, it may be possible to raise the temperature to 200°F with less than 2.4 kilowatts but it will require more time to do it.

300-5.3.5 DRYING WITH INFRARED RAYS. Equipment for producing heat by the use of infrared rays is now available in some shipyards. This is an effective method of drying insulation and is readily controlled.

300-5.3.6 DRYING WITH CIRCULATING CURRENTS. It is sometimes difficult to dry large machines satisfactorily by the use of external heating only. After removal of as much moisture as possible by this method, drying may be hastened by circulating current throughout the windings from an external, low voltage, current source. This should be provided with means for adjusting the voltage to limit the current through the windings. Exciter sets or voltage arc welding sets are suitable sources of current. When the windings which are to be dried are of equal resistance and current-carrying capacity (such as the phase windings on the stators of ac machines or the windings on field poles), they may be grouped in series or parallel depending upon which is best suited to the voltage available. A decision as to whether direct or alternating current is to be used should be based upon the following considerations:

a. Direct current should be used for the field windings of both ac and dc machines for dc armatures.

b. Either direct or alternating current may be used for the stator windings of ac generators and motors except that alternating current should be used only when the rotor of the machine is removed. Otherwise the rotor may be heated excessively.

300-5.3.6.1 Drying Small Machines. Circulating current from an external source may also be used for drying small machines. When there are a number of these of the same size and rating, their windings may be connected in series to suit the voltage available.

300-5.3.6.2 Drying with Machine's Operating Power. A generator which is in running condition can be dried without an external source of current by short circuiting the stator phase windings or armature leads, applying partial field, and driving the machine at reduced speed. The current should be carefully controlled by means of the field and speed to prevent overheating.

300-5.3.6.3 Precautions Using Circulating Current. The following precautions should be observed when drying machines by circulating current:

a. Even though the voltage required for circulating current through windings is usually low, it is important that the winding be reasonably free from moisture before this drying method is employed. Current should not be circulated through any winding which has an insulation resistance of less than 50,000 ohms at room temperature.

b. Current should not be conducted into a dc armature through brushes resting on a stationary commutator. This will cause localized heating of the commutator. The armature should be rotated continuously by some external means if it is necessary to dry by means of circulating current.

c. When drying by circulating current, the temperature must be increased slowly. Embedded temperature detectors or thermometers on the outside of the insulation will not indicate the hottest spot or copper temperatures. Temperatures measured by embedded detectors or by the hot resistance method should not exceed 91°C (195°F). Temperatures measured by thermometers should not exceed 77°C (170°F).

d. When using circulating current for drying ac stators, it is important that the stator end windings be heated sufficiently to drive out the moisture. The end windings on large machines have a large radiating surface, and unless heating with circulating current is supplemented with external heating, the temperature of the end windings will be considerably less than the temperature of the embedded section of the coils and the result will be insufficient drying of the end windings. The use of external heaters to increase the temperature of the end windings will avoid this difficulty. In addition, on machines of 1,000 kW or more, it is advisable to untape the end windings to facilitate moisture escape.

300-5.3.7 INSULATION RESISTANCE AND DRYING PROGRESS. The degree to which the properties of insulation are restored by drying may be determined to some extent by measuring the insulation resistance to ground. Readings should be taken when the drying is started, checked at regular intervals thereafter as long as the drying continues, and plotted on semi-logarithmic paper with the logarithm of insulation resistance ordinate and time as abscissa. Usually the resistance will drop as the machine warms up, reach a minimum, and then start to rise rapidly at first and then more slowly as the drying progresses. The value may decrease slightly at times and then increase again at a slower rate as the moisture is driven out, indicating that the drying is nearly completed. An erratic curve may indicate leakage paths to ground or weak insulation. Duplicate machines may show entirely different response to drying.

300-5.3.7.1 Preferred Method of Measuring Insulation Resistance. The preferred method of measuring insulation resistance is to use an insulation resistance measuring instrument of the handcrank generator type. Another method is to use one or two 45-volt B batteries and a 150-volt high resistance (at least 15,000 ohms) voltmeter of known internal resistance. If no B batteries are available, it is permissible to use a low voltage (not more than 120-volt) dc circuit provided a voltmeter test is first made to see if the circuit is grounded. See paragraph 300-3.2.4 for instructions on how to make this test and detailed instructions on how to measure insulation resistance by the voltmeter method.

300-5.3.7.2 When Drying is Completed. As drying continues, the general trend of the insulation resistance values indicate the progress in eliminating moisture. Drying should be continued until either the insulation resistance readings show no abrupt changes and do not increase more than 5 percent over a 12-hour period or the polarization index is greater than 3.0. The final value of insulation resistance for machine windings at the completion of drying, adjusted to 25°C, should not be less than the applicable minimum value given in the insulation resistance tables of paragraph 300-3.4.8.

300-5.3.8 CHECK ON COMPLETENESS OF SALT REMOVAL. The behavior of insulation resistance after drying can be used to furnish a check on the completeness of salt removal from equipment which has been splashed with or submerged in saltwater. To make this check, measure the insulation resistance while the equipment is still hot from the drying process, and at frequent intervals as it cools to room temperature. Then allow the equipment to stand idle at room temperature for at least 2 days after the equipment is cold and preferably a longer period if time is available. The humidity should be high in the room where the equipment stands. Pans of water should be placed on heating coils if necessary. Measure the insulation resistance at frequent intervals. If feasible, let a machine which has not been subjected to saltwater and reconditioned stand in the same room and compare its insulation resistance with that of the reconditioned machine. If the insulation resistance of the reconditioned machine falls rapidly when standing cold in a humid atmosphere, or if its insulation resistance is materially less than that of the other machine, the indications are that salt has not been completely removed and that the machine should be washed and dried again before proceeding with any further steps.

300-5.4 PERMANENT RECONDITIONING OF ELECTRICAL EQUIPMENT WHICH HAS BEEN SUBMERGED

300-5.4.1 POSSIBILITY OF REPLACEMENT. If electrical equipment has been submerged for an appreciable length of time, consideration should first be given to replacement of entire units, especially in the case of small apparatus, or damaged components or assemblies. It is often impossible to recondition certain types of equipment satisfactorily, and in many cases replacement will be more expedient than reconditioning. Where reconditioning is justified, replacement will also afford ample time for restoring the damaged equipment to serviceable condition after which it will be available for installation on other ships or as spares. Time required for the procurement of suitable new equipment and facilities available for reconditioning will also be deciding factors.

300-5.4.2 PRELIMINARY STEPS. When permanent reconditioning has been decided upon, the preliminary rust-preventive measures, cleaning, and salt and rust removal should be done in accordance with paragraphs

300-5.1.3 through 300-5.2.5.3. The following specific recommendations on details of reconditioning are based upon considerable experience and are considered necessary for accomplishing such work in minimum time with assurance of future continuous reliable operations.

300-5.4.3 DC GENERATORS AND MOTORS. Permanent reconditioning should include all the following items.

300-5.4.3.1 Armature Coils and Insulation. All coils should be removed from the armature core and, after the armature core has been reconditioned (paragraph 300-5.4.3.3), should be replaced with new coils or the old copper should be stripped, cleaned, and reinsulated. When rewinding, all slot cells, filler wedges, coil support insulation, banding wire, and banding insulation should be renewed.

300-5.4.3.2 Shunt Field Coils, Commutating Winding, and Compensating Winding. Remove all coils and windings from the poles and replace with new coils or reinsulate the original copper. All insulation between the poles and coils should be renewed.

300-5.4.3.3 Armature Cores. If the core is submerged for less than 12 hours and the depth of submergence is less than 5 feet, the core need not be disassembled unless the laminations are loose or there is reason to believe from careful surface inspection after surface deposits and rust have been removed, that salt deposits or corrosion are present between laminations or that the core varnish has been damaged. If the core is submerged for more than 12 hours or the depth of submersion exceeds 5 feet, or if considered desirable from surface inspection, loosen the core assembly sufficiently to fan out or separate a number of punchings at the end of the core so they may be examined for salt deposit, corrosion, or damage to the core varnish between laminations.

300-5.4.3.3.1 Where a number of machines have been submerged under identical conditions, a representative number of armatures should be opened to enable estimating the probable extent of damage to all armatures and determination of the measures necessary to recondition them. Complete salt removal from laminated cores is practically impossible. If maximum reliability is required the core laminations should be replaced.

300-5.4.3.3.2 If corrosion or damage has occurred, the punchings should be replaced if new ones are obtainable. Where replacement is not possible, punchings may be reconditioned provided corrosion has not been so extensive as to decrease materially the cross-sectional area thus increasing the flux densities or weakening the punching mechanically. Distortion during disassembly must also be avoided if punchings are to be reconditioned. If possible, armature punchings which are to be reconditioned should be returned to the manufacturer since special varnishes, equipment, and processes are usually required for such work. If it is not possible to return punchings to the manufacturer for reconditioning, each punching should be thoroughly cleaned with washing compounds or solvents as required, and the original core varnish removed. The punchings should then be revarnished and the cores rebuilt with no less than the original amount of steel.

300-5.4.3.3.3 If inspection shows that corrosion between punchings and damage to the core varnish are negligible and that salt or oil has not penetrated between punchings, the core should be reclamped. The exterior surfaces of such cores, and also of armature cores which have not been opened for inspection, should be cleaned. All rust should be removed but care must be taken that the edges of the laminations are not burred together, thus short circuiting the punchings. To ensure elimination of all moisture, the core should then be baked for approximately 10 hours at 127°C (260°F). The core assembly should then be treated to impregnate and seal it thoroughly. Depending upon the type of varnish or compound used, this may be done while the core is still hot from baking or after it has cooled to approximately room temperature. The treatment may consist of vacuum pressure impregnation and baking, dipping or spraying and baking, or spraying with air-drying varnish, depending upon the facilities available. Care must be taken that excess amounts of varnish or compound are not deposited on the slot surfaces nor in ventilating ducts, thus decreasing the slot dimensions and coil clearances or restricting ventilation.

300-5.4.3.4 Shunt Field Poles. Coils and insulation should be removed from pole pieces and oil and rust removed. If there is a possibility that oil has penetrated between punchings, the pole assembly should be degreased, preferably with a vapor degreasing system. The pole assembly should also be washed in fresh water by immersion to remove all seawater or salt deposits. The washing should be followed by baking and varnish treatment in accordance with paragraphs 300-4.5.8.2 through 300-4.5.8.4. Pole surfaces which join the frame or yoke should not be varnished since this will increase the reluctance of the magnetic path. If pole pieces are dipped or sprayed, all varnish should be removed from these surfaces.

300-5.4.3.5 Commutating Poles. Commutating poles are usually of solid construction. After removal of the coil and insulation, the pole piece should have all oil and rust removed. If pole pieces are laminated, the treatment should be as outlined in paragraph 300-5.4.3.4 for shunt field poles.

300-5.4.3.6 Commutators. Commutators should be completely disassembled and copper segments cleaned by means of cleaning compounds, solvents, or a pickling solution. All mica between segments and V-ring insulation must be renewed. Rebuilt commutators should be thoroughly seasoned. Clamping bolts should be evenly tightened with a torque wrench.

300-5.4.3.7 Brushes and Brush Rigging. Brushes and brush holder insulation should be replaced. Brush holders, studs, and connectors can usually be cleaned and restored to service. If the brush springs, pins, and so forth are corroded, they should also be renewed.

300-5.4.3.8 Shafts. Shafts should be checked for trueness and straightened if necessary. All traces of rust should be removed from the shaft journals by means of a fine stone or non-metall ic abrasive cloth. Slight pitting on a journal does not necessarily mean the bearing will not operate satisfactorily. If pits are present,however, all rough edges should be removed.

300-5.4.3.9 Bearings. All roller or ball bearings should be renewed. The grease in this type of bearing usually prevents extensive rusting but many cases of failure have been reported where bearings appeared to be in good condition and were not replaced. Slight imperfections which may not be detected by visual inspection may easily cause failure in ball or roller bearings. Small pits or grooves in sleeve-type babbitt bearings may be smoothed out with a scraper. More extensive damage will require replacement or rebabbitting.

300-5.4.3.10 Frames, Brackets, Bearing Pedestals, Fans, and Covers. These items should be thoroughly cleaned and washed preparatory to painting. Unless these parts have been broken or mechanically weakened by corrosion, there should be no difficulty in restoring them to service. Fans should be carefully inspected for weakness due to corrosion and replaced where there is any doubt as to their mechanical strength.

300-5.4.3.11 Terminal Connectors and Cables. All cable should be renewed. Terminal connectors may be reclaimed by cleaning or should be replaced if cleaning is not expedient. See also paragraph 300-5.4.6.

300-5.4.3.12 Insulation Resistance. Insulation resistance of windings on machines which have been permanently reconditioned should be in excess of the value given in the After Reconditioning in Shop column of the applicable table (see paragraph 300-3.4.10).

300-5.4.3.13 High-Potential Test. After insulation resistance has been measured and found to meet the requirements of the preceding paragraph, the windings should be given a high-potential test in accordance with paragraph 300-3.5.3.

300-5.4.4 AC GENERATORS AND MOTORS. Ac rotating machines used aboard naval ships consist of the following three general types: salient pole generators and motors; cylindrical rotor turbine-driven generators; and induction motors. The component parts of these machines should be reconditioned as follows.

300-5.4.4.1 Stator Coils. Stator coils should be removed from the core and replaced with new coils or the old copper reinsulated. When rewinding, all slot cells, filler wedges, coil end blocking, and lacing should be renewed.

300-5.4.4.2 Stator Cores. Stator cores should be treated as outlined for dc armature cores in paragraph 300-5.4.3.3. The stator cores in some induction motors driving auxiliary equipment cannot readily be disassembled since welding is employed for clamping the punchings together. Cores of this type should be scrapped and replaced with complete new cores if there is any question regarding their fitness for service.

300-5.4.4.3 Salient Pole Rotor Coils. These should be replaced or removed from the poles and the copper thoroughly cleaned and reinsulated. The insulation between the pole, coil, and collars should be renewed.

300-5.4.4.4 Salient Pole Cores. These should receive the same treatment as outlined for shunt field poles in paragraph 300-5.4.3.4.

300-5.4.4.5 Generator Rotors - Cylindrical Type. This type of rotor should be completely rewound with new copper, or with the original copper, provided it is removed without damage or excessive distortion. All insulation, slot cells, filler, coil end blocking, and taping should be replaced with new materials. The rotor body consisting of a forging integral with the shaft must be carefully cleaned and all rust removed. Rotors of this type are carefully machined and care must be taken that the rotor surfaces are not scratched or marred during reconditioning. Scratches may develop into cracks and eventually cause failure in high-speed rotors of this type. Additionally, for two pole sets the rotor coil retaining rings require special attention. They must be kept free from moisture to prevent the start of stress corrosion cracking (SCC). These rings, which are made of nonmagnetic MnCr alloys, become susceptible to SCC in the presence of moisture and can result in failure under the high stresses present. The retaining rings should be dye penetrant inspected whenever the rotor will be removed for overhaul/repair. Any pits or cracks shall be removed prior to reassembly.

300-5.4.4.6 Phase Wound Induction Motor Rotors. All coils should be removed and old copper reinsulated, or new coils and insulation provided. All slot cells, filler wedges, banding, and banding insulation should be renewed. The rotor core should be treated in the same manner as outlined in paragraph 300-5.4.4.2 for the stator core.

300-5.4.4.7 Squirrel Cage Induction Motor Rotors. Construction of this type of rotor usually prevents loosening of the core to permit inspection of the surfaces between laminations. Since it is impossible to determine the extent of corrosion or damage without practically destroying the rotor, it is recommended that the core and squirrel cage assembly be renewed if there is any question regarding fitness for service.

300-5.4.4.8 Collector Rings. Collector ring insulation and the leads connecting the winding to the rings should be renewed. After the rings are cleaned and assembled in position, they should be checked for eccentricity. If the wearing surface is damaged because of corrosion or mishandling, or is eccentric, a light cut should be taken in a lathe to restore the surface to satisfactory condition.

300-5.4.4.9 Frames, Covers, Brackets, Bearing Pedestals, Bearings, Shafts, Brushes and Brush Rigging, Fans, and Terminals. These should be reconditioned in accordance with the methods outlined for dc generators and motors. See paragraph 300-5.4.3.10.

300-5.4.4.10 Insulation Resistance and High-Potential Test. The same instructions apply as for dc machines, see paragraphs 300-5.4.3.12 and 300-5.4.3.13.

300-5.4.5 CONTROL EQUIPMENT. To properly recondition control equipment such as motor controllers, bus transfer switches, static power supply battery chargers, relays, switches, and similar equipment which have been submerged in saltwater, it is necessary to disassemble it completely. Recommendations on reconditioning of principal component parts are as follows.

300-5.4.5.1 Panels. All instruments, switches, and relays should be removed. Steel panels should be thoroughly cleaned using cleaning compounds or solvents as necessary.

300-5.4.5.2 Miscellaneous. All wiring, transformers, reactors, control and operating coils, compensators, arc chutes, fuses, capacitors, and all porous insulators and spacers should be replaced with new equipment.

300-5.4.5.3 Instruments. Instruments should be removed from mountings and opened to permit examination. It is usually more expedient to replace instruments completely than to attempt to renew damaged parts. It may take as long to obtain new parts as would be required to obtain a complete meter and services of experienced meter repairmen. Facilities of a meter laboratory are necessary for proper repair work.

300-5.4.5.4 Contactor Armatures. These should be cleaned and all rust removed. Laminated armatures should be examined for damage due to rust, all salt deposits should be removed, and the armature should be dried and impregnated in a manner similar to that for cores of rotating machines outlined in paragraph 300-5.4.3.3. Contacting surfaces should be cleaned of all varnish or impregnating compound to permit proper seating and elimination of sticking or chattering. Pivot joints should be similarly cleaned and oiled slightly.

300-5.4.5.5 Resistors. Insulating materials which will absorb saltwater will require replacement. Resistors and rheostats embedded in glossy ceramic or vitreous enamel material need only be rinsed in freshwater and dried. Grid-type resistors may be cleaned and reclaimed; all insulating materials should be replaced.

300-5.4.5.6 Circuit Breakers. Type ALB circuit breakers should be replaced. Type AQB circuit breakers should be disassembled and all metallic and molded insulating parts cleaned, rinsed in freshwater, and dried. Arc chutes and porous insulating parts should be replaced. Type ACB circuit breakers should be disassembled and metallic and molded insulating parts cleaned, rinsed in freshwater, and dried. All wiring, coils, and arc chutes should be replaced.

300-5.4.5.7 Bus Bars. All bus work should be completely disassembled and cleaned, using solvents or a pickling bath, as required. Plating and oxidation should be removed from contact surfaces, after which they should be silver plated.

300-5.4.6 CABLE. All Navy-type shipboard cable, except small miscellaneous wires used mainly on switchboards and internal wiring of equipment, is provided with an outer impervious sheath. This sheath is watertight and highly resistant to the usual oils, acids, and other fluids encountered aboard ship. So long as the impervious sheath remains intact and cable end seals stay tight (or loose end seals are not submerged), the cable should not be injured by submersion, and can carry current while submerged if the pieces of equipment connected to its ends are above water, or if submerged, are in watertight enclosures. It should also be serviceable for continued use after it has been submerged.

300-5.4.6.1 Submerged Cable. Cable which has been submerged should be tested after flooded compartments have been pumped dry. To test, disconnect cable from equipment at both ends; thoroughly clean outside of cable ends and end seals with freshwater if cable ends have been submerged; dry by wiping and apply heat externally to drive off surface moisture; and measure insulation resistance. See section 3 for instructions on measurement of insulation resistance and interpretation of measured insulation resistance taking into account length, size, and type of cable, and temperature at which the measurement is made.

300-5.4.6.2 Cable Reconditioning. If insulation resistance per foot of cable is above the minimum safe insulation resistance (see paragraph 300-3.3.2.2), the cable should be kept in service. If insulation resistance per foot of cable is lower, the low resistance may be due to conditions at the cable ends or to moisture in the cable. The insulation resistance of cable is likely to be lower than usual after an extended period of idleness irrespective of whether the cable has been submerged or not. Consequently, the cable should be treated in accordance with paragraphs 300-4.6.2 through 300-4.6.3.2 to see if the insulation resistance can be raised. In addition, a short piece can be cut off each end of the cable provided that there is enough slack so that cable shortening will not prevent making electrical connections at its ends without strain, and will not leave cables which pass up to rotating equipment, such as a director or gun mount, with a bight too short to prevent injurious strains on cables at all points of strain. The low insulation resistance section of a cable is often confined to a very short length near the ends. If insulation resistance can be raised to or above the minimum insulation resistance per foot of cable as given, the cable should be kept in service. If, however, insulation resistance remains low, the cable length should be examined for any visible evidence of damage to the protective impervious sheath. If no external damage is apparent, the cable should be treated again. If all efforts outlined above have been tried without success, or if inspection shows that the sheath has been punctured, the cable should be replaced. The permanent replacement cable should be in a single length without splice.

300-5.4.7 RECONDITIONING OF MISCELLANEOUS EQUIPMENT. There are various types of shipboard electrical equipment on which specific instructions for reconditioning have not been outlined. Methods for cleaning, drying, replacement of damaged material, and restoring to service, however, are essentially the same for all such equipment and the foregoing instructions are intended to offer guidance in the rehabilitation of all types of naval electrical equipment which has been submerged in seawater.

300-5.4.8 PAINTING PERMANENTLY RECONDITIONED ELECTRICAL EQUIPMENT. After permanently reconditioning electrical equipment, it should be painted in accordance with **NSTM Chapter 631, Volume 2, Preservation of Ships in Service (Surface Preparation and Painting).**

300-5.5 TEMPORARY RECONDITIONING OF ELECTRICAL EQUIPMENT WHICH HAS BEEN SUBMERGED

300-5.5.1 RELIABILITY. Permanent reconditioning of electrical equipment which has been submerged is preferable to temporary measures when time, material, and facilities required for permanent reconditioning are available. Occasions will undoubtedly arise, however, when time, material, and facilities are insufficient for permanent reconditioning but circumstances make it necessary to restore electrical equipment to service for temporary or limited operation.

300-5.5.1.1 Results of Incomplete Salt Removal and Correction. Measures which usually suffice for temporary reconditioning require less time and trouble than those needed for permanent reconditioning but the results obtained are inferior. It is very difficult to remove salt completely from insulation which has been submerged. Salts which are left after incomplete removal following submergence are hygroscopic, absorb moisture from air when a machine is cold, and cause insulation resistance to drop. It may rise when the machine dries out in use only to fall again when it cools off. Such a condition is obviously unsatisfactory since even when it does not lead to eventual breakdown it destroys confidence in the reliability of the machine. In order to guard against this possibility, as practical, insulation resistance should be checked, after drying, in accordance with the procedure given in paragraph 300-5.3.8. Unless this check is satisfactory, further washing and drying are necessary before the machine can be considered satisfactory, even for temporary or limited operation.

300-5.5.1.2 Periodic Testing. Furthermore, for at least 4 months after being placed in service, a machine which has been reconditioned for temporary or limited operation should be carefully watched and, except in an emergency, should be limited to use in operations which would not endanger the ship or personnel if the reconditioned machine should fail. During the 4-month (or longer) period following restoration to service, insulation resistance measurements should be made at frequent intervals, at least once a week. Insulation resistance measurements should include measurements made immediately after shut-down while the machine is still hot, measurements when the machine has cooled to ambient temperature after shutdown, and measurements after standing at ambient temperature until the machine is to be used again. If insulation resistance throughout the entire 4-month period is above the minimum values given in the Before Cleaning columns of the tables referenced in paragraph 300-3.4.10 and is, in addition, comparable to that of similar machines which have not been submerged, and if no difficulties are experienced in operation, it may be concluded with a reasonably high degree of assurance that the reconditioning has been completely successful and that nothing more need be done to make the machine fit for continued service. If, on the other hand, insulation resistance is abnormally low following a period of idleness in which there was opportunity to absorb moisture from the air, or insulation resistance is erratic as compared with similar machines which were not submerged, or trouble is experienced in operation, the machine should be permanently reconditioned at the first opportunity.

300-5.5.2 PROCEDURES. Steps involved in reconditioning equipment for temporary operation consist essentially of cleaning and washing with freshwater to remove salt (see paragraph 300-5.2.1 through 300-5.2.5.3), drying (see paragraphs 300-5.3.1 through 300-5.3.8), replacement of defective parts (see paragraph 300-5.5.3), and varnish treatment (see paragraphs 300-4.5.8 through 300-4.5.8.9). In addition, paragraphs 300-5.5.5 through 300-5.5.8.2 contain detailed instructions specifically applicable to different items of equipment.

300-5.5.3 PART REPLACEMENT. After drying is complete, all equipment should be inspected for defective parts. Hygroscopic material used for slot sticks, spacing blocks, pole collars, and insulation may swell when wet, and shrink after drying to the point where replacement is necessary. Coil lacing and blocking may also require renewal. Wound rotors of induction motors and dc armatures should be carefully checked to see that the banding is tight. Collector ring and commutator insulation must be carefully inspected for defects.

300-5.5.4 VARNISH TREATMENT. After drying, insulation resistance values can usually be further improved by the application of varnish. Small equipment should be dipped and baked. Larger apparatus can usually be dipped and baked using the pan method of dipping (paragraph 300-4.5.8.4). Where dipping by the pan method is impractical, spray coats of air-drying varnish may be used. One or two thin coats of varnish should be sufficient. The unnecessary and frequent application of heavy coats of varnish usually results in more harm than benefit since it makes heat dissipation more difficult and surface cracks may eventually develop. See paragraphs 300-4.5.8 through 300-4.5.8.9 for detailed information on varnishes and varnish treatments.

300-5.5.5 DC GENERATORS AND MOTORS. Dc armatures are difficult to clean and dry because water may be trapped inside the commutator. If commutator construction permits, two bolts or studs diametrically opposite or alternate bolts or studs should be removed to allow drainage of trapped water and thorough washing and drying. If hot air is circulated through these bolt holes during drying, the drying time can be materially reduced. These commutator bolts or stud nuts are originally tightened to a definite tension which permits thermal expansion of the commutator segments without distortion of full load and speed. Prior to removal, the initial setting of the bolts or stud nuts should be marked to enable replacement at the proper tension. On smaller machines the construction may be such that the front clamping ring must be removed to permit drainage. If this is done, the commutator should be securely banded before removing the clamping ring in order to prevent collapse of the segments. After reassembly, the commutator should be checked for eccentricity, turned, and the mica undercut, as necessary.

300-5.5.5.1 Preferred Drying Technique. Vacuum drying is preferable. If commutators are dried at an atmospheric pressure, several days may be required to obtain an insulation resistance of 1 megohm and even then the machine may not be thoroughly dry.

300-5.5.5.2 Optional Drying Technique. In case a vacuum tank is not available, a heated enclosure or oven may be utilized with hot air blown under the commutator bars if possible. Armatures should be turned frequently to allow the escape of trapped water. After as much moisture as possible has been removed by external heating, the drying may be expedited by circulating current through the field windings. Insulation resistance readings should show values of at least 50,000 ohms at room temperature before the application of circulating current.

300-5.5.5.3 Drying with Circulating Current. If the windings have been dried sufficiently to permit the application of reduced voltage, a dc machine may be further dried by driving it with the armature short-circuited and the field energized. If the machine has a series field, it should be left out of the circuit or reversed to buck the shunt field, and the armature short-circuited through an ammeter and circuit breaker or fuse. Sufficient load current can then be circulated through the short circuit until the desired temperature is obtained by means of field speed control. Extreme care must be taken when the short circuit is first put on, for if the series field is left in and is not bucking the shunt field, the generator will build up on residual magnetism and act as a series generator short-circuited.

300-5.5.5.4 Banding Check. After the insulation resistance has reached a constant value at least equal to that given in the appropriate table referenced in paragraph 300-3.4.10, all slot wedges, filler, and so forth should be examined for shrinkage and replaced if necessary. The banding should be checked for looseness.

300-5.5.5.5 Fault Tests. The armature should be tested for faults. See paragraphs 300-4.7.10.5 , 300-4.7.11.2, and 300-4.7.12.2.

300-5.5.5.6 High-Potential Test. After completion of the varnish treatment, armatures of machines having a rating of 100 kilowatts or greater should receive a high-potential test (paragraph 300-3.5.3) for 1 minute at a voltage not to exceed 150 percent of rated voltage. Tests at a voltage higher than rated voltage are not necessary on smaller machines.

300-5.5.5.7 Reconditioning Field Poles of a DC Machine. The same difficulty exists in reconditioning the field structure of a dc machine as in reconditioning the rotor of a salient pole ac machine (see paragraph 300-5.5.8). If pole and coil removal is found necessary, all parts must be carefully cleaned and if possible the coils should be dried in a vacuum tank. Drying should be continued until the insulation resistance is equal to or more than the values in the appropriate table of paragraph 300-3.4.10.

300-5.5.5.7.1 After assembly and varnish treatment, the fields of dc machines should be given a high-potential test (paragraph 300-3.5.3) for 1 minute at a voltage equal to four times the normal voltage applied to the field.

300-5.5.6 AC STATORS. After removing the rotor, clean and wash with freshwater in accordance with paragraphs 300-5.2.1 through 300-5.2.5.3. Washing should be followed by drying in accordance with instructions in paragraphs 300-5.3.1 through 300-5.3.8. Large stators may require drying by circulating current as well as by external heating.

300-5.5.6.1 Suitability for Service. To determine suitability for service, ac stators having a rating of 100 kilowatts or greater should be subjected to a high potential test (paragraph 300-3.5.3) for 1 minute at a voltage not exceeding 150 percent rated voltage. This test should be made subsequent to varnish treatment. Tests at a voltage higher than rated voltage are not necessary on machines of smaller size.

300-5.5.7 CYLINDRICAL-TYPE AC ROTORS. Owing to constructional features of windings and insulation in rotors of this type, it is very difficult to restore them to service without complete rewinding and reinsulating. For emergency operation, thorough washing and drying may be tried in accordance with methods previously outlined but results will be extremely uncertain.

300-5.5.8 SALIENT-POLE-TYPE AC ROTORS. The principal difficulty in washing and drying rotors of this type is in restoring the necessary insulation resistance between field coils and poles. Corrosion on pole pieces and salt deposits around coils, poles, and pole collars, usually require removal of poles and coils. If washing and drying the rotor assembly is not successful, poles and coils should be disassembled and all rust and salt removed. Pole insulation will usually require replacement. Insulation between coil turns may require replacement depending upon the type used and the method of impregnation.

300-5.5.8.1 Collector Ring Leads and Collector Insulation. Collector ring leads and collector insulation require careful cleaning and inspection for damage. Failure due to current leakage across the surface of insulation at these points is not uncommon.

300-5.5.8.2 High-Potential Test. After reconditioning, salient pole rotors in machines having a rating of 100 kilowatts or greater should be subjected to a high-potential test (paragraph 300-3.5.3) for 1 minute at a voltage equal to four times the normal voltage applied to the field.

300-5.6 PERMANENT RECONDITIONING OF ELECTRICAL EQUIPMENT WHICH HAS BEEN SPLASHED

300-5.6.1 STATEMENT OF PROBLEM. The steps involved in permanently reconditioning equipment which has been splashed with water are essentially the same as those involved in reconditioning equipment which has been submerged. The primary problem involved is the correct determination of just how many steps are necessary in a specific case to do a satisfactory job. When equipment has been splashed with clean freshwater, drying may be all that is needed for complete and permanent reconditioning. When equipment has been splashed with saltwater, cleaning and washing with freshwater to remove salt and subsequent drying may be enough. On the other hand, when equipment has been splashed with saltwater over an extended period of time, as, for example, by saltwater leaking from an air cooler and falling on generator or motor windings, the measures necessary to recondition the equipment permanently and satisfactorily may be quite as extensive as are necessary for submerged equipment.

300-5.6.2 RECOMMENDED PROCEDURE. Carefully inspect equipment that has been splashed and investigate the circumstances under which it was splashed in order to have reliable data as a basis for estimating probable damage and extent of reconditioning work that will be necessary. In arriving at a decision, remember that it is better to do a little more work than absolutely necessary than a little less.

300-5.6.2.1 After equipment has been cleaned and dried, but before any varnish has been applied, check completeness of salt removal by the procedure described in paragraph 300-5.3.8. If this indicates that salt has not been completely removed, the equipment should be washed and dried again before any further steps are taken. After the equipment has been restored to service, it should be watched for 4 months or longer and a report on insulation resistance should be submitted.

300-5.7 PERMANENT RECONDITIONING OF ELECTRICAL EQUIPMENT THAT HAS BEEN SPLASHED WITH LITHIUM BROMIDE

300-5.7.1 GENERAL. Lithium bromide solutions used in refrigeration systems when spilled or splashed on electric motors may cause irreversible damage. The motor should be flushed with freshwater at the time of discovery of the splash to diminish the possibilities of ground paths, and to help to prevent the lithium bromide from creeping between the laminations. Cleaning and drying should be done according to paragraphs 300-5.2 through 300-5.3.2.6.

300-5.7.2 CONTAMINATED WINDINGS OR LAMINATIONS. To determine if the windings or the laminations have been contaminated the cleaned and dried motor should be immersed in freshwater having a conductivity of 500+50 micromhos/cm and with a nonionic wetting agent added. TRITON X-100 in a 0.1 percent proportion has been found suitable. After 24 hours submergence, if the conductivity of the water has increased by more than 10 percent the windings should be stripped and the bare core retested for another 24 hour submergence period. If the water conductivity has increased by more than 10 percent the laminations are considered to have been penetrated by the spill and shall be replaced. Replacement laminations should be furnished with C-5 core plate. The conductivity of the freshwater may be increased by the addition of sodium bicarbonate. In each above test a new batch of freshwater should be used.

300-5.7.3 ACCEPTABILITY. If the wound core in the first test of paragraph 300-5.7.2 does not show an increase of conductivity of the test water, the wound core is considered free of contamination. The winding should now be dried and checked. If the insulation resistance of the winding is less than the value shown in the After Cleaning in Ship column of the applicable table to paragraph 300-3.4.10, the windings should be replaced.

APPENDIX A.

ELECTRICAL INSULATING MATERIALS

300-A.1 SCOPE

300-A.1.1 GENERAL. Table 300-A-1 through Table 300-A-10 provide pertinent data concerning insulating materials carried in the Navy Supply System. The data has been prepared to assist repair personnel in the selection of the correct electrical insulating materials for the maintenance and repair of electrical equipment.

300-A.1.1.1 Availability of Materials. It is obvious that not every type, form, class, and size of insulating material is carried in the Navy Supply System. Materials that require purchase from commercial suppliers should be one those that conform to the latest edition of the applicable military specification.

Table 300-A-1 ROUND FILM INSULATED MAGNET WIRE (J-W-1177)[5]

Round magnet wire. Film coated type round magnet wire shown on shipboard electrical equipment drawings may be listed as T2, B2, L2, H2, K2, M2, or with other numeric suffixes. The number indicates the insulation film thickness. No number indicates single, 2 indicates heavy, 3 means triple, and 4 is quadruple. The letter symbols indicate the temperature class: T = 105° C, B = 130° C, L = 155° C, H = 180° C, K = 200° C, M = 220° C. Fibrous coverings may be shown as G2V, Dg, or Dg2. The G means a single glass serving; G2 means double glass; V means varnished. Dg means single Dacron-glass and Dg2 means a double Dacron-glass serving. Round magnet wire shall be utilized as follows:

Present Magnet Wire Types	Recommended Rewind Magnet Wire Types[8]	
T, B, L, H, K, M	M	
T2, B2, L2, H2, K2, M2	M2	
T3, B3, L3, H3, K3, M3	M2	
T4, B4, L4, H4, K4, M4	M2	
BV, G2V, Dg, Dg2, TGV, T2GV, T2G2V,	DGg, BDg2, BDgV, BDg2V, B2Dg2	For 155°C Ins. Sys.
BGV, B2GV, BDg, B2Dg2, B2Dg2V,	H2GX, H2G2X	For 200°C Ins. Sys.
LDg, L2Dg2, L2Dg2V, HDg, H2Dg,	LDgH, LDg2H, L2DgH, L2Dg2H	For 180°C Ins. Sys.
HDgG, H2DgG, MDgGM, M2DgGM	M2DgGM	For 220°C Ins. Sys.

AWG	Type	NSN 6145-00	Weight (lb)	AWG	Type	NSN 6145-00	Weight (lb)	AWG	Type	NSN 6145-00	Weight (lb)
#7	M2	937-8587	250	#20	M	937-8368	75		M	937-7852	8
					M2*	937-8368	75	#31	M2*	937-7852	8
#8	M2	937-8585	200								
				#21	M	937-8366	75	#32	M	937-8231	8
#9	M2	937-8583	250		M2*	937-7864	75		M2*	937-8575	8
#10	M2	937-8410	250	#22	M	937-8243	75	#33	M	937-8561	8
					M2*	937-8579	75		M2*	937-8573	8
#11	M2	937-8408	75								
				#23	M	937-8563	75	#34	M	937-8229	8
#12	M2	937-8406	75		M2*	937-8211	75		M2*	937-7866	8
#13	M2	937-8404	75	#24	M	937-8241	75	#35	M	937-8644	2
					M2	937-8392	75		M2*	937-8197	2
#14	M	937-8376	75								
	M2*	937-8581	75	#25	M	937-7848	75	#36	M	937-8642	2
					M2*	937-8213	75		M2*	937-8201	2
#15	M	937-8374	75								
	M2*	937-7862	75	#26	M	937-8239	75	#37	M	937-8640	2

Table 300-A-1 ROUND FILM INSULATED MAGNET WIRE (J-W-1177)[5] - Continued

Round magnet wire. Film coated type round magnet wire shown on shipboard electrical equipment drawings may be listed as T2, B2, L2, H2, K2, M2, or with other numeric suffixes. The number indicates the insulation film thickness. No number indicates single, 2 indicates heavy, 3 means triple, and 4 is quadruple. The letter symbols indicate the temperature class: T = 105° C, B = 130° C, L = 155° C, H = 180° C, K = 200° C, M = 220° C. Fibrous coverings may be shown as G2V, Dg, or Dg2. The G means a single glass serving; G2 means double glass; V means varnished. Dg means single Dacron-glass and Dg2 means a double Dacron-glass serving. Round magnet wire shall be utilized as follows:

Present Magnet Wire Types	**Recommended Rewind Magnet Wire Types**[8]	
T, B, L, H, K, M	**M**	
T2, B2, L2, H2, K2, M2	**M2**	
T3, B3, L3, H3, K3, M3	**M2**	
T4, B4, L4, H4, K4, M4	**M2**	
BV, G2V, Dg, Dg2, TGV, T2GV, T2G2V,	**DGg, BDg2, BDgV, BDg2V, B2Dg2**	**For 155°C Ins. Sys.**
BGV, B2GV, BDg, B2Dg2, B2Dg2V,	**H2GX, H2G2X**	**For 200°C Ins. Sys.**
LDg, L2Dg2, L2Dg2V, HDg, H2Dg,	**LDgH, LDg2H, L2DgH, L2Dg2H**	**For 180°C Ins. Sys.**
HDgG, H2DgG, MDgGM, M2DgGM	**M2DgGM**	**For 220°C Ins. Sys.**

AWG	**Type**	**NSN 6145-00**	**Weight (lb)**	**AWG**	**Type**	**NSN 6145-00**	**Weight (lb)**	**AWG**	**Type**	**NSN 6145-00**	**Weight (lb)**
					M2*	937-8390	75		M2*	937-8209	2
#16	M	937-7858	75								
	M2*	937-8402	75	#27	M	937-8237	75	#38	M	937-7854	2
#17	M2	937-8400	75		M2*	937-8215	75		M2*	937-8203	2
#18	M	937-8372	75	#28	M	937-7850	75	#39	M	937-8227	2
	M2*	937-8398	75		M2*	937-8577	75		M2*	937-8386	2
	M2	937-8887	75								
				#29	M	937-8235	75	#40	M	937-8638	2
#19	M	937-8370	75		M2*	937-8199	75		M2*	937-8384	2
	M2*	937-8396	75								
				#30	M	937-8233	8	#41	M	937-8636	2
					M2*	937-8207	8		M2*	937-5871	2
								#42	M	937-8634	3/4
									M2*	937-8205	3/4
								#43	M2*	937-8569	3/4
								#44	M2*	937-8382	3/4

Table 300-A-1 ROUND FILM INSULATED MAGNET WIRE (J-W-1177)[5] - Continued

Round magnet wire. Film coated type round magnet wire shown on shipboard electrical equipment drawings may be listed as T2, B2, L2, H2, K2, M2, or with other numeric suffixes. The number indicates the insulation film thickness. No number indicates single, 2 indicates heavy, 3 means triple, and 4 is quadruple. The letter symbols indicate the temperature class: T = 105° C, B = 130° C, L = 155° C, H = 180° C, K = 200° C, M = 220° C. Fibrous coverings may be shown as G2V, Dg, or Dg2. The G means a single glass serving; G2 means double glass; V means varnished. Dg means single Dacron-glass and Dg2 means a double Dacron-glass serving. Round magnet wire shall be utilized as follows:

Present Magnet Wire Types	Recommended Rewind Magnet Wire Types[8]	
T, B, L, H, K, M	M	
T2, B2, L2, H2, K2, M2	M2	
T3, B3, L3, H3, K3, M3	M2	
T4, B4, L4, H4, K4, M4	M2	
BV, G2V, Dg, Dg2, TGV, T2GV, T2G2V,	DGg, BDg2, BDgV, BDg2V, B2Dg2	For 155°C Ins. Sys.
BGV, B2GV, BDg, B2Dg2, B2Dg2V,	H2GX, H2G2X	For 200°C Ins. Sys.
LDg, L2Dg2, L2Dg2V, HDg, H2Dg,	LDgH, LDg2H, L2DgH, L2Dg2H	For 180°C Ins. Sys.
HDgG, H2DgG, MDgGM, M2DgGM	M2DgGM	For 220°C Ins. Sys.

AWG	Type	NSN 6145-00	Weight (lb)	AWG	Type	NSN 6145-00	Weight (lb)	AWG	Type	NSN 6145-00	Weight (lb)

NOTES:

1. Unit of Issue (U/I) is reel for AWG #7 through #29 and spool for AWG #30 through #44.
2. Preferred magnet wire types are designated *.
3. AWG Sizes 42, 43, and 44 were formerly supplied in 2-lb spools.
4. In instances where these types of wire are not available per Federal Spec J-W-1177, the NEMA Standard Publication No. MW 1000 for magnet wire as listed on the applicable J-W-1177 slash sheet can be substituted.
5. J-W-1177, Wire, Magnet, Electrical, General Specification.
6. Sequence of preference for substituting magnet wire type: M → K → H. Film thickness should be equal or less than that of original wire.
7. Use of respooled magnet wire should be avoided if possible.
8. Materials specified in a NAVSEA certified rewind procedure shall be used in lieu of the materials in this table, when there is a difference between the two. When the OEM drawings specify a different wire type, and it is known that the insulation system has not been upgraded, or when the wire removed can be typed, that wire type can be used in lieu of type M.

Table 300-A-2 SQUARE AND RECTANGULAR FILM INSULATED MAGNET WIRE (J-W-1177)[1]

Square and Rectangular magnet wire. Equipment drawings should list the rewind size to use. Square and rectangular magnet wire should be utilized as follows:		
Present Magnet Wire Types	**Recommended Rewind Magnet Wire Types**[3]	
T2, B2, L2, H2, K2, M2	M2	
T3, B3, L3, H3, K3, M3	M4	
T4, B4, L4, H4, K4, M4	M4	
GV, G2V, Dg, Dg2,	BDg, BDg2, BDgV, BDg2V, B2Dg, B2Dg2	For 155°C Ins. Sys.
TGV, T2GV, T2G2V,	H2GX, H2G2X	For 200°C Ins. Sys.
BDg, B2Dg, B2Dg2,	LDgH, LDg2H, L2DgH, L2Dg2H	For 180°C Ins. Sys.
LDg, L2Dg, L2Dg2,	M2DgGM[2]	For 220°C Ins. Sys.
MDgGM, M2DgGM		

NOTES:
1. J-W-1177, Wire, Magnet, Electrical, General Specification.
2. In instances where these types of wire are not available per Federal Spec J-W-1177, the NEMA Stand Publication No. MW1000 for magnet wire as listed on the applicable J-W-1177 slash sheet can be substituted.
3. Materials specified in a NAVSEA certified rewind procedure shall be used in lieu of the materials in this table, when there is a difference between the two. When the OEM drawings specify a different wire type, and it is known that the insulation system has not been upgraded, or when the wire removed can be typed, that wire type can be used in lieu of type M.

Table 300-A-3 (PART 1) FLEXIBLE INSULATION SHEET

Slot and phase insulation. Slot and phase insulation may also be designated as ground insulation, slot linear, basic insulation, core insulation, or just insulation. Drawings may show any of the following materials as slot and phase insulation: mica glass, fish paper, varnished cambric, mylar, DMD, silicone mica glass, varnished glass, mica paper. Slot and phase insulation shall be utilized as follows:	
Present Slot and Phase Insulation	**Recommended Rewind Slot and Phase Insulation**
Mica-glass types (MIL-I-3503) Mica paper types (MIL-I-21070)	For equipment rated over 600 volts use Mica-glass composites (MIL-I-3505).
Fish paper and composites (MIL-I-695) Polyethylene-terephthalate composites DMD (MIL-I-22834) Mylar (MIL-I-631)	For equipment rated 600 volts and below use POLYAMIDE paper (MIL-I-24204)

Table 300-A-3 (PART 2) FLEXIBLE INSULATION SHEET

MIL-I-24204 POLYAMIDE PAPER FEDERAL SUPPLY CLASS 5970* (FOR EQUIPMENT RATED 600 VOLTS AND BELOW)			
Thickness	**Width (in.)**	**Length (in.)**	**NSN 5970-00-**
0.005	36	36	016-3053
0.007	36	36	016-3342
0.010	36	36	016-3367
0.015	36	36	016-3375
0.020	36	36	016-3377
0.030	36	36	016-3492

Table 300-A-3 (PART 3) FLEXIBLE INSULATION SHEET

MICA GLASS COMPOSITES FEDERAL SUPPLY CLASS 5870* (FOR EQUIPMENT RATED OVER 600 VOLTS)					
Thickness	**Width (in.)**	**Length (in.)**	**NSN 5970-00-**	**Type**	**Class**
0.007	36	36	198-8415	Mg	H
0.010	36	36	198-8417	Gmg	H
0.010	36	36	198-8420	Mg	B
0.012	36	36	198-8421	Gmg	B
0.012	36	36	198-8416	Gmg	H
0.007	36	36	198-8419	Pmg	B
0.015	36	36	244-2659	Pmg	B

Table 300-A-4 (PART 1) INSULATION SLEEVING

Sleeving. Older types of sleeving crack when bent thus causing a likely spot for eventual failure at a joint or connection. Present types of sleeving must meet a 90 degree bend test. Sleeving shall be utilized as follows:	
Present Type of Sleeving	**Recommended Types for Rewind**
Cotton braid A-A-1, A-A-2 (MIL-I-3190C)	For class A, B or F insulation systems, use acrylic-glass (class 155) For class H or N insulation systems rewound with Class F system thermally upgraded materials, use silicone rubber glass (class 200) on AC equipment and polyamide glass (class 220) on AC or DC equipment
Glass braid B-A-1, B-B-1 (MIL-I-3190C)	Insulation system
Glass braid H-A-1, H-B-1, H-C-1 (MIL-I-3190C) Glass braid, vinyl (MIL-I-21557B)	Use silicone rubber glass (class 200) on ac systems and polyamide-glass (class 220) on dc systems

Table 300-A-4 (PART 2) INSULATION SLEEVING

MIL-I-3190C Acrylic Glass (Temperature Index 155) Federal Supply Class 5970, U/I ft.				MIL-I-3190C Silicone Rubber Glass (Temperature Index 200) Federal Supply Class 5970 U/I ft.			
Size No.	Nominal ID (in)	Wall Thick-ness (in)	NSN 9G 5970-00-	Size No.	Nominal ID (in)	Wall Thick-ness (in)	NSN 9G 5970-00-
24	0.022	0.030	488-7811	18	0.042	0.030	838-7278
22	0.027	0.030	488-7794	17	0.047	0.030	025-1789
20	0.034	0.030	488-7792	16	0.053	0.030	825-3680
18	0.042	0.030	488-7789	15	0.059	0.030	025-1788
17	0.047	0.030	488-7784	14	0.066	0.045	825-3678
16	0.053	0.030	488-7477	12	0.085	0.045	953-8478
15	0.059	0.030	488-7448	11	0.095	0.045	025-1782
14	0.066	0.045	488-7447	10	0.106	0.045	025-1781
13	0.076	0.045	488-7431	9	0.118	0.045	578-9037
12	0.085	0.045	488-7429	8	0.133	0.045	852-2654
11	0.095	0.045	488-7261	7	0.148	0.045	825-3677
10	0.106	0.045	488-7208	5	0.186	0.045	025-1780
9	0.118	0.045	488-7046	4	0.208	0.045	025-1779
8	0.133	0.045	488-7043	3	0.234	0.045	285-0489
7	0.148	0.045	488-7016	2	0.263	0.055	025-1778
6	0.166	0.045	488-7014	1	0.294	0.055	285-0490
5	0.186	0.045	488-6997	0	0.330	0.055	025-1777
4	0.208	0.045	488-6918	3/8	0.387	0.055	852-4758
3	0.234	0.045	488-6917	7/16	0.450	0.065	
2	0.263	0.055	488-6648	1/2	0.512	0.065	285-0492
0	0.330	0.055	488-6623	5/8	0.640	0.065	
3/8	0.387	0.055	488-6621	3/4	0.768	0.075	285-0493
5/8	0.640	0.065	488-6592	7/8	0.893	0.075	
3/4	0.768	0.075	488-6464	1	1.018	0.075	
7/8	0.893	0.075	488-6244				
1	1.018	0.075	488-5710				

Table 300-A-4 (PART 3) INSULATION SLEEVING

MIL-I-3190C Polyamide Glass (Temperature Index 220) Federal Supply Class 5970, U/I ft.			
Size No.	Nominal ID (in)	Wall Thickness (in)	NSN 5970-00-
16	0.053	0.030	488-5091
14	0.066	0.030	488-5087
12	0.085	0.045	488-5082
10	0.102	0.022	488-4991
8	0.133	0.045	488-4942
6	0.166	0.045	488-4883
2	0.263	0.055	488-4660
0	0.330	0.055	

Table 300-A-5 LAMINATED INSULATION SHEET (U/I LB)

MIL-P-15037 Glass Melamine, Type GME (Temp., Index 130)[1]	
Thickness (in)	**NSN 5970-00-**
0.031	912-1907
0.062	905-8336
0.125	912-1908
0.250	912-1909
Glass Polyester, Type SG 200 (Temp., Index 200)[2]	
0.031	
0.064	
0.094	NSN Numbers Later
0.125	
0.250	
NOTES: 1. Suitable for class 155°C applications for slot wedges and coil separators. 2. Available from the Glastic Company, 4321 Glenridge Road, Cleveland, Ohio 44121	

Table 300-A-6 (PART 1) LACING AND TYING TAPE

Lacing and tying cords and tapes have been made from twisted cords, braided cords and braided flat tapes using cotton, flax or glass yarns. Finishes applied to these materials to improve knot strength and application have been waxes, synthetic rubbers and resin coatings. Lacing and tying tape shall be utilized as follows:	
Present Types	**Recommended Type**
Glass cord (MIL-Y-1140) Cotton cord (MIL-T-713) (Also flax, hemp or resin)	Polyamide, Type V Finish A (natural) per MIL-T-43435A

Table 300-A-6 (PART 2) LACING AND TYING TAPE

MIL-T-43435A. POLYAMIDE TAPE - HEAT RESISTANT, FLAT BRAIDS, FEDERAL SUPPLY CLASS 5970 (Cont'd)					
NSN 5970-00-001	**Size**	**Width (in)**	**Thickness (in)**	**Breaking Strength (lb)**	**U/I Yds per Spool**
9356	1	0.200	0.016	85	250
9357	2	0.110	0.014	50	250
9358	3	0.090	0.012	35	500
9359	4	0.055	0.01	25	500

Table 300-A-7 (PART 1) INSULATION TAPE (U/I ROLL)

MIL-Y-1140 TAPE, TEXTILE, GLASS, UNTREATED, ECC-B FEDERAL SUPPLY CLASS 8315			
NSN 8315-00-	**Width (in)**	**Thickness (in)**	**Break Strength (lb)**
290-8265	3/8	0.003	45
290-8256	3/8	0.007	115
290-8266	1/2	0.003	60
290-8260	1/2	0.005	135
290-8264	3/4	0.003	95
290-8259	3/4	0.005	225
290-8254	3/4	0.007	225
290-8258	1	0.005	310
290-8278	1	0.007	240
MIL-I-15126 TAPE, ADHESIVE, GLASS BACKING FEDERAL SUPPLY CLASS 5970 (TEMP. INDEX 155)			
NSN 5970-00-	**Width (in)**	**Thickness (in)**	**Dielectric Strength (volts)**
543-1154	1/2	0.007	1000
686-9151	1	Any	Any
MIL-I-19166 TAPE, ADHESIVE, GLASS BACKING FEDERAL SUPPLY CLASS 5970 (TEMP. INDEX 200)			
NSN 5970-00-	**Width (in)**	**Thickness (in)**	**Dielectric Strength (volts)**
709-0045	0.625	0.007	2000
933-1406	0.250	0.007	2000
650-5345	0.500	0.012	4000

Table 300-A-7 (PART 2) INSULATION TAPE (U/I ROLL)

MIL-I-24391 TAPE, ADHESIVE, PLASTIC BACKING, BLACK FEDERAL SUPPLY CLASS 5970 (TEMP. INDEX 105)		
NSN-5970-00-	**Width (in)**	**Thickness (in)**
419-3164	1.000	0.0085
419-4291	0.750	0.0085
419-4290	0.500	0.0080

Table 300-A-8 LEAD WIRE (MIL-W-16878)

AWG	Diameter (in)	NSN 6145
Type EPDM (Ethylene-Propylene Diene Elastomer) Class 150° C, 600V		
18	0.142	01-212-4772
16	0.155	01-212-4773
14	0.170	01-212-4774
12	0.197	01-212-8028
10	0.252	01-212-1603
8	0.327	01-212-1604
6	0.383	01-270-8558

Table 300-A-8 LEAD WIRE (MIL-W-16878) - Continued

AWG	Diameter (in)	NSN 6145
4	0.440	01-212-1341
2	0.494	01-212-4775
Type FF Sil. Rubber Gl. Braid (Class 200)[1]		
22	0.100	00-284-1480
20	0.108	00-284-1481
18	0.118	00-284-1482
16	0.127	00-284-1483
14	0.176	00-284-1484
12	0.195	00-284-1485
10	0.215	00-284-1486
8	0.327	00-284-1487
6	0.356	00-284-1488
4	0.412	00-284-1489
2	0.495	00-284-1490
1	0.552	00-284-1491
0	0.598	00-284-1492
00	0.651	00-284-1493
0000	0.775	00-284-1494
Type EE Tetrafluoroethylene (Class 200)		
24	0.054	01-995-1603
22	0.060	00-643-2494
20	0.068	00-811-2232
18	0.079	01-062-4011
16	0.089	00-089-6563
14	0.100	00-089-6289
12	0.124	01-089-6562
10	0.145	01-957-1985
8	0.207	00-542-6677

NOTES:
1. Silicone lead wire shall not be used in non-ventilated brush type machines.

Table 300-A-9 (PART 1) VARNISH INSULATION

MIL-I-24092 CLEAR, BAKING, SOLVENT TYPES			
Class	**NSN 5970-00-**	**U/I**	**Thinner**
155	931-2413	1 gal can	Xylene
155	931-1170	5 gal can	Xylene
200	931-2414	5 gal can	Xylene
200	548-7211	1 gal can	Xylene

Xylene thinner is grade B per TT-X-916: NSN 6810-00-584-4070, 5 gal

Table 300-A-9 (PART 2) VARNISH INSULATION

MIL-I-24092 CLEAR, AIR-DRYING, SOLVENT TYPE				
Grade	**NSN 5970-01-**	**U/I**	**Thinner**	**Mfr. Brand No.**
CA	190-5473	1 gal can	Mineral spirits	AC 41 Dolph
CA	252-7481	1 gal can	Mineral spirits	AC 43 Dolph
Mineral spirits is grade I per TT-T-291: NSN 8010-00-558-7026, 5 gal				

Table 300-A-9 (PART 3) VARNISH INSULATION

MIL-I-24092 VARNISH, CLEAR, AIR-DRYING TYPE				
Type	**NSN 5970-01-**	**U/I**	**Mfr.**	**Part No.**
CA	078-5636	1 gal	Sterling	U-122

Table 300-A-9 (PART 4) VARNISH INSULATION

RED INSULATING VARNISH - AIR DRY[1]			
Type	**U/I**	**NSN**	**Mfr. Brand No.**
Air dry - moisture, oil, and salt water resistant	16 oz spray can	5900-00-076-8988	ER-41 RED
NOTE: 1. For SWBD buswork, frame coating, etc			

Table 300-A-9 (PART 5) VARNISH INSULATION

SOLVENTLESS BAKING VARNISH FOR DIPPING FOR USE ON SUBMARINE EQUIPMENT		
Composition	**Mfr Brand No.**	**Mfr.**
POLYESTER	Esterlite 605	Epoxylite
POLYESTER	Isolite 862M	Schenectady Chemical

Table 300-A-10 SLOT WEDGE INSULATION

MIL-I-(later) FORMED POLYAMIDE PAPER (U SHAPE) FEDERAL SUPPLY CLASS 5970; U/I-feet; FSCM (Mfgr code) - 87952				
Shape	**Width (in)**	**Thickness (in)**	**NSN 5970-00-**	**Mfgr Type**
Curve	5/32	11/64	004-4491	NHT 70-30
Curve	7/32	3/16	004-4490	NHT 86-30
Curve	1/4	7/32	004-4489	NHT 99-30
Curve	5/16	1/4	004-4488	NHT 117-30
Curve	3/8	5/16	004-4487	NHT 144-30
Square	5/32	7/32	004-4486	NHT 30-10-14
Square	1/4	11/64	004-4492	NHT 30-16-11
Square	23/64	1/4	004-4493	NHT 30-23-16

APPENDIX B.

CERTIFICATION PROCEDURE FOR PROVIDING MOTORS WITH A SEALED INSULATION SYSTEM

300-B.1 BACKGROUND

This appendix covers the procedure involved in obtaining certification for providing motors with a sealed insulation system. By using vacuum pressure impregnation with solventless epoxy varnish, coil taping, and the materials and procedures to seal winding connections, the sealed insulation system has demonstrated excellent moisture resistance when compared to either the conventional varnish dip-and-bake method or the obsolete encapsulation method.

300-B.2 REQUIREMENTS

Only activities certified by NAVSEA in accordance with MIL-STD-2037 may rewind motors with a sealed insulation system. The cost of becoming certified is borne by the activity becoming certified. Repair facilities afloat are not included in this program due to space constraints for vacuum-pressure impregnating (VPI) equipment and materials.

300-B.3 CERTIFICATION PROCEDURE

Activities desiring to become certified to do sealed insulation work must contact NAVSEA prior to beginning the certification procedure identified in MIL-STD-2037.

APPENDIX C.

CERTIFICATION PROCEDURES FOR REFURBISHMENT OF SUBMARINE SHIP SERVICE MOTOR-GENERATOR SETS

300-C.1 BACKGROUND

This appendix covers the procedure involved in obtaining certification to refurbish ship service motor-generator sets using vacuum-pressure impregnating methods and material. By using these methods and improved winding techniques both stator and rotor windings have shown greatly improved resistance to moisture and carbon dust when compared to other treatment methods.

300-C.2 REQUIREMENTS

Only those activities certified by NAVSEA to do so may refurbish submarine ship service motor-generator sets.

300-C.3 CERTIFICATION PROCEDURE

Certification will be accomplished in the following sequence:

1. Procedure Preparation
   - a The refurbishment facility shall prepare a refurbishment procedure for each type SSMG set, namely frequency, kW output, manufacturer's name, construction, etc. Any convenient format may be used for the procedure write-up; however, the following items must be included: title page, reference documents, general notes, incoming inspection, initial testing, stripping/cleaning, coil manufacture, winding and insulation, commutator refurbishment, electrical testing, varnishing and final testing. Details of procedure preparation, insulation and testing is obtained from NAVSEA.
   - b The refurbishment facility shall submit the refurbishment procedure to NAVSEA for review and acceptance.
   - c NAVSEA will advise the refurbishment facility by letter of the approval status of the procedure. If the procedure is unsatisfactory, the refurbishment facility must revise the procedure in accordance with NAVSEA comment and resubmit for further NAVSEA review and acceptance.
2. Sample Coils
   - a After NAVSEA has approved the procedure, the refurbishment facility shall prepare a sample coil of each category winding (AC stator, DC arm, and others). The sample coils shall use the same material and procedures as that in the NAVSEA approved procedure to demonstrate the adequacy of the varnishment method. The sample coils shall be the same size, same orientation as the motor-generator and the straight section of the sample coils shall be enclosed in a pseudo slot so that the varnish penetration occurs primarily through the end turn area. Details of sample coil construction and cutting procedures are provided by NAVSEA.
   - b NAVSEA representative will visit the refurbishment facility to inspect the facility set-up and witness sample coil construction and treatment. The sample coils are cut in sections in the presence of the NAVSEA representative so that the fill of void space can be examined. The criteria for acceptance of the sample coils is stipulated in Appendix B of S6269-AC-GYD-010/SHIPS, **Refurbishment Inspection Guide for M/G Set** - the ″Criteria for Qualification of VPI Process of Varnish in Sample Coils for Submarine Motor Generator Sets.″
3. Certification

a First Stage - Upon satisfactory completion of the above steps, the facility is qualified to refurbish an actual SSMG rotor or stator. NAVSEA will issue a letter of First Stage certification to the refurbishment facility.

b Final Stage - NAVSEA representative will visit the refurbishment facility during the first refurbishment to review the material used, workmanship, witness all insulation tests, and inspect the finished product.

4. Quality Assurance Coils

a NAVSEA requires a sample coil of each winding category of each succeeding refurbishment (the cutting pattern same as in attached instructions). The coil pieces package should be marked with: date of refurbishment, model number and manufacturer. This package is delivered to NAVSEA for file and quality control purposes.

5. Recertification

a Three years after the original facility certification, another set of sample coils shall be prepared and cut in sections per the attached instructions. The cut-up sections shall be sent to NAVSEA for examination and recertification. If situation is warranted, NAVSEA reserves the right to include sequences A, B and C above in its recertification program.

APPENDIX D.

BANDING ARMATURES WITH RESIN-TREATED FIBROUS-GLASS BANDING TAPE

300-D.1 ADVANTAGES OF GLASS BANDS

300-D.1.1 GENERAL. Resin-impregnated glass bands have several advantages over steel-wire bands when used to hold coils in place on electric motor and generator armatures.

300-D.1.2 INSULATION ELIMINATION. As non-conductors, glass bands eliminate both creepage problems and the requirement for insulated pads between band and coil except in large machines having spacing between coils.

300-D.1.3 ARC RESISTANCE. Most glass bands have good resistance, a quality that helps eliminate flashover failures.

300-D.1.4 LASHING ELIMINATION. Damage caused by electrical failure which can burn through steel bands is minimized by eliminating the lashing of wires from the steel bands.

300-D.1.5 HEAT RESISTANCE. Glass bands are able to withstand emergency operation at 260° C (500° F) for short periods without failure. Such temperatures may cause loss of solder and even failure of a steel-wire band.

300-D.1.6 EASE OF INSTALLATION. Application of glass bands to the armature is relatively easy.

300-D.1.7 SAFETY. The possible danger to the operator from breaking and lashing of stressed steel-wire bands during the banding operation is eliminated. Glass bands are made of high-tensile-strength glass yarns laid parallel and bonded with thermosetting resins. In most cases, they are as strong as steel bands. Sufficient tension can be applied during the banding operation to assure holding the coils in place at any rated operating speed and for expected overspeeds.

300-D.2 GLASS BANDING MATERIALS

CAUTION

Some of the available materials are assembled with cross threads of glass to prevent separation of the longitudinal fibers.

Since these cross threads in banding applications actually reduce band strength, it is recommended that banding material with all threads parallel (no cross threads) be used for armature banding.

300-D.2.1 MATERIAL. Glass tape for banding purposes is made of nonwoven fiber glass yarn laid parallel and impregnated with polyester, epoxy, or acrylic thermosetting resins for bonding. The strength of the tape is the result of the many parallel fibrous glass filaments so oriented that all filaments share the tensile load, and the glass-to-resin ratio is high. The resin holds the glass fibers in place, thereby preventing rubbing of the fibers. The resin molds to the equipment being banded and prevents movement of the band after it is cured.

300-D.2.2 STORAGE. The material must be stored at a temperature of 4° C (40° F) (moderate refrigeration) or below to prevent unnecessary shortening of the shelf life of the impregnating resins. Exposure to lower temperatures will not harm the resin. Exposure to temperatures above about 20° C (68° F) for extended periods (several days) can make the material useless. When its shelf life has passed, the resin in the banding material has cured and therefore the material is of no use. The shelf life under proper storage conditions is about 6 months. Close watch of ordering and use schedules should be kept.

300-D.2.3 SIZE. Resin-impregnated banding tapes are supplied in various widths from 1/4 to 1 inch wide. Tape thickness varies from 0.010 to about 0.014 inch. Except for small armatures with bands less than 1 inch wide, the 1-inch wide banding material is preferred and should be used.

300-D.2.4 APPLICATION. The material is delivered in a semi-cured state and is usually relatively dry and non-sticky. Several manufacturers' tapes tend to become tacky and difficult to run through the tension device if they become too warm. Return of such material to a refrigerator for a short period will cool the tape and assist in reducing the tacky condition.

300-D.2.5 CURING. The curing cycle of the resin-impregnated banding materials is from 4 to 5 hours at a temperature of 135 to 150° C (275 to 302° F). When in doubt, 5 hours at 150° C (302° F) should ensure a proper cure. A higher temperature will accelerate the cure. Curing of the resins into satisfactory bands will not occur at temperatures below 120° C (248° F) regardless of the length of exposure time. When the resin cures, it becomes a stiff, hard, springy, homogenous mass binding the glass fibers and anchoring the band in place.

300-D.2.6 SLOW CURING RESINS. Phenolic varnishes (and air in the case of some polyesters) may slow down the cure of some resins, although they usually will not prevent cure. Where the possibility exists that this may cause such trouble, a layer of very thin mylar film covering the band during the curing cycle will prevent difficulties. When such a film is used on the band, the release (nonadhering) side of the film should be placed next to the band to keep the mylar from sticking to the band after curing the resin. After curing the band, the mylar covering is untied and removed. The cured bands usually have a continuous temperature rating of 150° C (302° F). Some of the newer materials, however, have a continuous temperature rating of 180° C (356° F). Temperatures of up to 260° C (500° F) for short periods (an hour or two) usually will not destroy the strength of the band.

300-D.2.7 PRECAUTIONS. When using resin-impregnated glass tape for banding several precautions are necessary to insure a completely satisfactory job.

300-D.2.7.1 Age. Be sure the material used for the band is not past its useful shelf life.

300-D.2.7.2 Use Schedule. Tape should be stored at 4° C (40° F) for a shelf life of no more than 6 months (use old stock first).

300-D.2.7.3 Critical Temperature. When baking the armature to cure the resin-impregnated glass band, check the oven to be sure the correct temperature is being used. A bad thermometer can mean uncured bands.

300-D.2.7.4 Inhibiting Agents. Take precautions against inhibiting cure by exposure to phenolic varnish or other materials. Some polyester resins are air inhibited and should be covered during cure cycle.

300-D.2.7.5 Limits. Never bring the band as far as the core, since this would prevent varnish treatment from getting to the coil insulation under the band.

CAUTION

Do not replace magnetic steel-wire bands with glass band.

300-D.2.7.6 Magnetic Steel-Wire Bands. Magnetic steel-wire bands should not be replaced with glass bands because the magnetic steel-wire band is usually part of the magnetic circuit, carrying part of the commutating pole flux. A change to a glass band is apt to disturb the flux configuration in the commutating zone with consequent commutation problems. This could involve changing the commutating air gaps and/or field strength to restore the commutation to an acceptable level. Magnetic steel-wire bands can be readily detected with a magnet. Some NAVSEA technical manuals make reference to the type of bands in the text or on the included drawings. Occasionally armatures are observed having had magnetic steel-wire bands installed in error at some previous date. When any question arises regarding the proper band replacement contact NAVSEA.

300-D.3 PREPARATIONS FOR BANDING

300-D.3.1 PRELIMINARY STEPS. Perform preparatory steps as described in the following paragraphs.

300-D.3.1.1 Quantity Needed. Determine the amount of glass band to be used. When banding an armature that was formerly banded with a steel-wire band, use a glass band with twice the cross-section area of the original steel-wire band. If the width of the glass band is to be the same width as the steel band, the total thickness of the glass band must be twice the thickness of the steel band it replaces. The glass band can be at least as wide as the insulation under the steel band; therefore, by making it wider than the original steel band, its thickness can be reduced proportionally. Since no insulation is needed under the glass band, the total outside diameter over the top of the glass band generally will not be much greater than that over the top of the steel band. For example, if the drawing or inspection of the band removed from the armature shows a double steel-wire band of 0.072-inch-diameter wire and a bandwidth of 3 inches, the equivalent area of the glass band will be twice that of the steel band, or two times (0.072 inch thick x 3 inches wide x 2 layers) = 0.864 square inch. Assuming that the steel band insulation pad was 3-3/4 inches wide, the glass band can be 3-3/4 inches wide. Then, the minimum thickness of the glass band will be 0.864 square inch divided by 3.75 inches wide or 0.230 inch thick. It can be assumed that each layer or band will be 0.10-inch thick, so there will be about 23 layers of banding tape. When the top of the band is to be machined for any reason, add an additional 1/32-inch, or three turns, to be machined off.

CAUTION

Care must be used with small armatures so that excessive tension will not be used with resultant deforming of the coils being held in place.

See Table 300-D-1 for glass banding material for rotating assemblies.

300-D.3.1.2 Tension. Determine the pull-down tension, also called winding tension, of the resin-impregnated glass tape. It should be the same as the recommended steel-wire banding tension. In replacing two layers of steel wire, the average tension used for the outer and inner layers should be used for glass tape tension. This tension will pull the coils into their final position and will set up the glass, initially, so that the centrifugal force of the windings will not result in movement during operation of the equipment. Maximum tension of 600 pounds per inch of tape width should be used (i.e., 300 pounds maximum for 1/2-inch-wide tape).

300-D.3.1.3 Boundaries. Locate edges or boundaries of the glass bands on the armature. The edge of the band should not butt against the armature core, since this may prevent penetration of the varnish into the coil area under the band. On small armatures where less than 200-pound tension will be used on the banding tape, the boundary should be marked by a band of ordinary adhesive tape or other convenient means. When more than 200-pound tension will be used on the banding tape, side restraints will be needed. Since banding tapes do not have lateral strength, side restraints are needed to prevent side slippage during application and cure of the resin in bands under high tension. Side restraints should be at least as high as the band. Where economical, reusable fixtures, made of a material that is nonadhesive to the resin in the banding material or treated with a release (nonadhering) coating, may be used. A satisfactory disposable edge restraint may be made from a strip of Fuller-board or similar material wrapped around the armature and held in place by a few turns of banding wire or a shipping strap. Most convenient for repair work are edge-restraint strips consisting of glass and asbestos cordage, unimpregnated, and with a tail to be held in place by the band. They are commercially available in two sizes. The smaller, for bands up to 1/8-inch thick, consists of a 5/32-inch welt and 1-inch tail. The larger, for bands greater than 1/8-inch thick, has a 5/16-inch welt and a 3-inch tail. This type of restraint becomes a part of the band and is not removed after the band is cured.

300-D.3.1.4 Covering Strips. Prepare covering strips to cover large openings between windings in the band area. This prevents the lower turns of glass tape from being forced into the gaps by the upper layers of the band. Materials for this covering may be glass melamine or glass silicone laminate. It should be 0.032-inch thick, cut into strips wide enough to cover the gaps and approximately 9 to 12 inches long (as required by the armature size) with the edges lapped about 1/2 inch to permit shingling as the band tensions snugs the coils down against the coil supports.

300-D.3.1.5 Core Filler Strips. Where coils are below the core surface, filler strips of glass melamine, slightly less than slot width between the coils and band are needed to ensure that full pressure is maintained to pull the coils down to the bottom of the slots. Where filler strips are required, the edges should be smoothly rounded to prevent breaking of the glass yarns in the band.

300-D.3.1.6 Temporary Bands. Apply temporary bands, in the same manner as for steel banding. Banding tension should not be relaxed at any time during application of bands.

300-D.3.1.7 Balance. Balance the armature before winding the tape in place so that the weights can be incorporated in the band, if this method of attaching balancing weights is required.

300-D.3.2 TENSION DEVICE. The tension device for applying resin-impregnated glass bands to armatures must have flat, rotating pulleys and a tension drum and be capable of creating a steady, uniform tension of up to 600 pounds without damage to the tape.

NOTE

Wire banding tension devices with grooved pulleys or drag blocks cannot be used with glass tapes.

The device should feed the tape straight to the banding surface without twists or turns. The tape should be allowed to feed into the tension device by unwinding freely from a spool on a shaft that is well clear of the tension device. Devices for adapting standard banding machines or a lathe to glass tape banding are available from several manufacturers (see paragraph 300-D.6.3).

300-D.4 BANDING OPERATION

300-D.4.1 PROCEDURAL STEPS. After preparations for banding are complete, including the installation of temporary bands, the banding operation can start. The armature should be preheated to a temperature of 100 to 135° C (212 to 275° F). It is then mounted in the banding machine or lathe that has been fitted with a tension device suitable for applying tension to a impregnated glass banding material. Banding includes the following steps in the order of their occurrence.

1. Secure in place the covering strips, if needed, to close any large openings in the armature winding in the band area. This can be done with a string or cord which can be removed as the band covers the strips.
2. Tie a band of cotton tape or other suitable material around the core and attach one end of the glass tape from the tension device to the cotton tape. Then take one full turn around the armature to hold the glass tape.
3. Adjust the tension device to the desired tension. Proceed to apply the band, starting at the core end of the band moving to the outer edge of the band; then wipe the tape back and forth for the required depth until the band is completed.
4. Secure the last 4 to 6 inches of the end of the tape to the band with a hot, clean soldering iron and cut the tape.
5. Repeat steps 1 through 4 at each band of the armature.
6. Place the armature with the resin-impregnated bands in place in an oven for curing at 150° C (302° F) for 5 hours, or as indicated by the tape manufacturer's technical manual.
7. Remove the edge restraints (unless they are built in) and remaining temporary bands.

300-D.4.2 POST-BANDING TREATMENT. After the cure cycle is finished, remove any rough edges left on the band by light dressing with a file as the armature is turning. This can be done while machining the commutator or balancing the armature. Varnish treatments and other operations necessary to complete repair of the armature can then be completed and the armature reinstalled.

300-D.5 BALANCING THE ARMATURE

300-D.5.1 GENERAL. Balancing should be done to the extent possible without adding weights to the band. Propulsion motors and generators and magnetic minesweeping pulse generators are not to be balanced by addition of weights within banding. When it is necessary, however, to balance by adding weights to the band, or to complete the balance by adding a small weight to the band, three methods are feasible and, if properly carried out, will result in a satisfactory operation.

300-D.5.1.1 Early Method. The first method is acceptable provided the coils are in or near their final location as a result of temporary banding and will not be disturbed appreciably by final banding. In this method, final balancing is done before the glass bands are placed, and the balance weight (a piece of sheet lead, 1/16-inch thick) is cut and weighed by the balancer to suit and is located by marking the armature where the weight is to be applied. This weight is placed on a piece of flexible mica and after one or two layers of the banding tape are applied, is held in place as marked and wound under succeeding layers.

300-D.5.1.2 Band Turned Down. In the second method, the band is laid up about 1/32 inch thicker than necessary, and this additional thickness is turned off after the band is completely cured. This can be done at the time the commutator is turned. It leaves a smooth contour for the addition of balance weights. Balancing is done by placing weights at proper points on the band to achieve balance. Sheet lead about 1/16 inch thick which has been copper plated can be secured to the band by an epoxy adhesive. A balancing weight so placed on an armature should be secured in place by several complete turns of a thermosetting glass adhesive tape around the armature.

300-D.5.1.3 Weighted Epoxy. A third method of balancing uses a lead weighted epoxy that can be applied to the glass band for balance. The lead weighted epoxy is available with a catalyst (see Table 300-D-2). Since the material mixed with the catalyst has a useful life of 15 to 30 minutes, mixing must be done only as immediately required. The compound is placed on the cleaned surface of the band where the weight is needed. A 250-watt infrared lamp or curved heat unit placed 12 inches away will harden the compound in 15 minutes sufficiently to permit further balancing. Air cure occurs in 1 to 2 hours.

300-D.6 MATERIALS

300-D.6.1 BANDING MATERIALS. Materials listed in Table 300-D-1 have been found suitable and are recommended for use. Procure locally for immediate use. Resin treated fiberous glass banding tape should meet MIL-I-24178.

300-D.6.2 AUXILIARY MATERIALS. Materials listed in Table 300-D-2 have been found suitable and are recommended for use. Non-stock items should be procured locally for immediate use.

300-D.6.3 TENSION DEVICES. The following devices have been found suitable and are recommended for use.

Potter & Rayfield, Inc. No. 3 Goodson St. Bristol, VA 24201	(Type FA unit accommodates either wire or glass tape)
Klein Armature Works 1439 North Elm Street Centralia, Illinois 62801	(For glass tape only)

NOTE

For those shops desiring to construct their own tension device, drawings, instructions and parts lists are available from David W. Taylor Research Center (DTRC), Bethesda, Maryland 20084.

Table 300-D-1 BANDING MATERIAL

Tape Designation	Supplier	Resin Type	Insulation Class
RES-I-GLAS 8022-G	Fibertech P.O. Box 4000 305 Beasley Drive Franklin, TN 37065	Polyester	130° C
RES-I-GLAS	Fibertech P.O. Box 4000 305 Beasley Drive Franklin, TN 37065	Acrylic	180° C
SCOTCH PLY XP 126	3M Company 900 Bush Avenue St. Paul, MN 55144	Epoxy	130° C

Table 300-D-2 (PART 1) AUXILIARY MATERIALS

Designation	Supplier	Tail Size (in)	Welt Size (in)
Size 5 Size 10 Size 12 Size 16	PEI 800 Martha Street Munhall, PA 15120	1 1 1-1/2 1	3/32 7/32 3/16 1/4
Size 5 Size 10 Size 12 Size 12S Size 16	Westinghouse Elec. Corp. West Mifflin, PA 15122 (WEC has a B stage resin in material)	1 1 1-1/2 4 2	3/32 5/32 3/16 3/16 1/4
Balancing materials (lead-filled epoxy)			
Epoxylite #8118 Balancing Compound	Epoxylite Corp. 9400 Toledo Way Irvine, CA 92713		
Band surface protector (Mylar with release agent)			
76850-3-54 G4	Insulating Materials Inc. 1 Campell Rd. Schenectady, NY 12306		

Table 300-D-2 (PART 2) AUXILIARY MATERIALS

Covering and filler strips				
Designation	**NSN 5970-00-**	**Thickness (in)**	**Insulation Class**	**I/U**
Glass melamine laminate, type GME, MIL-P-15037 sheets	892-3608	1/32	130° C	lb
Glass silicone laminate, type GSG, MIL-I-24768/17 sheets	198-8327	1/32	200° C	sh
(Do not use silicone laminates on enclosed dc machines.)				

Table 300-D-3 GLASS BANDING MATERIAL FOR ROTATING ASSEMBLIES

Machine	Armature				A.C. Field[2]				Exciter or Second A.C. Field			
	Front		Back		Front		Back		Front		Back	
	Width In Inches	Turns	Width In Inches	Turns	Width In Inches	Turns	Width In Inches	Turns	Width In Inches	Turns	Width In Inches	Turns
Safety 64 S6269-AH-MMA-010	4 1/8	48	2 3/4	32	1	32/7	1	32/7				
Safety 64 S6269-AK-MMA-010	4 1/8	48	2 3/4	33	1	36/8	1	36/8				
Allis Chalmers 64 S6269-AF-MMA-010	4 5/8	25	3 1/2	19	1	57/12	1	57/12				
Allis Chalmers 64 363-1050	3 7/8	49	2 3/8	31	1	71/15	1	71/15				
Safety 43 363-1085	4 13/16	46	3	29	3/4	57/7	3/4	35/7	7/8	9/2	7/8	9/2
Safety 43 363-1015	4 13/16	43	3	27	3/4	26/6	3/4	26/6				
Safety 43 363-0922	4 13/16	47	3	29	3/4	28/6	3/4	28/6				
EDY 43 S6269-AV-MMD-010	5	24	2 3/8	12	3/4	36/8	3/4	36/8				
Allis Chalmers 43 S6269-AP-MMA-010	3	42	2 3/8	33	1	56/12	1	56/12	7/8	3/1	7/8	3/1
Allis Chalmers 43 S9311-AY-MMA-010	3	24	2 3/8	19	1	40/8	1	40/8				
Westinghouse 363-0961	1 7/8	18	2	19	1	60/12	1	60/12	1[1]	62/13	1[1]	62/13

Table 300-D-3 GLASS BANDING MATERIAL FOR ROTATING ASSEMBLIES - Continued

Machine	**Armature**				**A.C. Field**[2]				**Exciter or Second A.C. Field**			
	Front		**Back**		**Front**		**Back**		**Front**		**Back**	
	Width In Inches	**Turns**	**Width In Inches**	**Turns**	**Width In Inches**	**Turns**	**Width In Inches**	**Turns**	**Width In Inches**	**Turns**	**Width In Inches**	**Turns**
Allis Chalmers 9311-AR-MMA-010	3 1/4	47	2 5/8	38	3/4	45/9	3/4[1]	45/9	3/4[1]	36/8	3/4[1]	36/8
Safety 5 S6269-AS-MMA-010					1/2	9/2	1/2	9/2				
Safety 5 363-0925					1/2	6/2	1/2	6/2				
Allis Chalmers 5 363-1040					1/2	4/1	1/2	4/1				

NOTES: This table is based on using 3/8 inch wide, 0.015 inch thick glass banding material.
1. Second A.C. Field
2. A.C. Field Calculated with Safety Factor 5/Safety Factor 1

APPENDIX E.

TRICKLE METHOD OF SHIPBOARD MOTOR REPAIR

300-E.1 DESCRIPTION

300-E.1.1 BACKGROUND. In recent years epoxy-type 100 percent solid (solventless) varnishes have been used on a case-to-case basis. These varnishes are applied by pouring or trickling the varnish over the end turns and allowing the varnish to penetrate the windings down through the slots. One advantage of this varnish procedure is that the varnishing time can be reduced considerably when compared to the regular procedure of three dips and bakes in a solvent-type varnish. Tests have shown that some solventless varnishes, when correctly applied, provide environmental protection to the windings equivalent to three dips and bakes in a class F solvent-type varnish but do not provide protection equivalent to sealed insulation system windings. Another advantage is that the varnishing can be done in place without removing the motor to a shop. Curing is by resistance heat generated when the windings are energized.

300-E.1.2 LIMITATIONS. This procedure applies primarily to the repair and rewinding in-place of drip proof ac random-wound induction motors rated for class B or lower temperatures. This does not provide authorization to varnish in-place motors for nuclear plant equipment. Any action to varnish in-place motors for nuclear plant equipment will be taken by the Nuclear Propulsion Directorate, NAVSEA 08.

300-E.1.3 REQUIREMENTS. The following procedure shall be followed by the shop electrical personnel in doing motor repair work using solventless varnishes.

300-E.1.3.1 Facilities. Provide for adequate facilities.

a. For initial check-out of procedure, use regular IMA shop facilities.
b. For actual in-place work, ensure that:
    1 Space is available for stripping the stator and up-ending the rewound core for varnishing.
    2 Low voltage dc power supply is available for energizing windings.
    3 Ventilation is sufficient for exhausting varnish fumes.

300-E.1.3.2 Personnel. Trained personnel are needed to do solventless varnish work. It is suggested that the following procedure be followed:

1. Select one, two or three personnel from the shop crew who are the most experienced stator winders.
2. Obtain the following supplier's bulletins on solventless varnish materials, review, and make available to key personnel.

    The Epoxylite Corporation
    9400 Toledo Way
    P. O. Box 19671
    Irvine, CA 92713-9671
    Sterling Division
    Reichhold Chemical Co.

9 Ohio Blvd.
Sewickley, Pennsylvania 15143
Bulletin E253-153
John C. Dolph Co.
Monmouth Junction, New Jersey 08852
Bulletin MSR-3-68-20M and 9-68-10M

300-E.1.3.3 Material. Obtain a trial kit (or sample) of each varnish material.

300-E.1.3.4 Shop Trials. Utilizing trained personnel, shop facilities, and stock material, strip and rewind three small ac motor stators (not over 5 HP) using a different varnish on each stator: use Epoxylite 236 material on #1 stator; Sterling E253-153 on #2 stator; and Dolphon CC1126A on #3 stator. The rewinding prior to varnishing should be done using the same materials (magnet wire, slot and phase insulation, wedges, sleeving, leads, and so forth) as required for the sample motors. Follow the instructions provided in the bulletins and the detailed procedures provided under paragraph 300-E.2 through 300-E.2.7. The stators should be ready for testing to determine suitability. Insulation resistance, surge comparison, and ac high-potential test should be done. Minimum IR should be 200 megohms.

300-E.1.4 SPECIAL CONSIDERATIONS. After completing the shop trials, actual repair jobs may be done. It is suggested that the ship or shore activity initiate its own repair program. Motors that cannot be removed to the shop for repair or where time does not permit may be rewound and solventless varnish treated in place. Solventless varnish treatment is not effective unless all aspects of the overall process are considered and resolved; therefore, each of the following items is important:

a. The iron core must be clean and free of dirt contamination. Laminations should be tight.
b. The winding should be energized and held at the required temperature for the time specified.
c. The solventless varnish should flow through, fill, and bond the windings in the slot portion and should fill and protect the end turns.
d. The air flow pattern should not be constricted by the varnish.

300-E.2 MATERIALS, EQUIPMENT, AND PROCEDURE

300-E.2.1 GENERAL. Necessary materials, equipment, and procedures for repair of shipboard ac induction motors by utilizing the trickle (or pour) method are discussed in the following paragraphs.

300-E.2.2 MATERIALS. Lower temperature curing materials are preferred for in-place work.

a. Epoxylite 236 is a two-component 100 percent solid epoxy resin system. Resin and catalyst are furnished as a unit package. Pot life of mix is 20 minutes and it cures at 66° C (150° F). Epoxylite Corporation is the manufacturer. Epoxylite 236 is available in one-pound (pint) (NSN 5970-00-001-9362) or two-pound (quart) (NSN 5970-00-001-9361) unit packages.
b. Sterling E253-153 is a two-component 100 percent solid epoxy resin system. Resin and catalyst are furnished separately. Pot life of mix is 8 hours at 25° C (77° F) and it cures at 110° C (230° F). Sterling Division,

Reichhold Chemicals Inc. is the manufacturer. Resin and catalyst are both available in one-pound unit packages (resin NSN 5970-00-001-7934; catalyst NSN 5970-00-001-7933).

c. Dolphon-CC1126A is a two-component 100 percent solid epoxy resin system. Resin and reactor (catalyst) are furnished as a kit. Pot life of mix is 12 hours at 21° C (70° F) and it cures at 135° C (275° F). John C. Dolph Co. is the manufacturer. Either one (NSN 5970-00-001-7935) or two-pound (NSN-5970-00-001-9360) packages are available.

300-E.2.3 EQUIPMENT. A low-voltage dc power source is needed to energize the windings to be varnished. Capacity should be large enough to maintain winding temperature for curing the particular varnish being used. Additional equipment includes:

a. Stator support jig for holding stator off the deck

b. Catch-pan for varnish drippings

c. Mixing containers, stirring sticks, and measuring scale (wt)

d. Thermocouple for measuring stator temperature

e. Auxiliary heat for curing tacky surfaces

f. Red devil blower for exhaust ventilation

g. Insulation system. The following insulating materials should be utilized for rewind work: however, materials specified on OEM drawings may also be used. It is imperative that these materials be used on encapsulation work.

   1 Magnet wire - type M2 (heavy build) J-W-1177-583

   2 Slot insulation and phase - Nomex, form S

   3 Slot wedge - spacers and fillers type GME

   4 Lead wire - silicon rubber, stranded, MIL-W-16878

300-E.2.4 STRIPPING AND CORE PREPARATION. The motor stator scheduled for in-place repair should be examined. Review motor drawings and technical manual for wire size, number of turns per coil, coil groupings, and connections. Old winding should be stripped out of the core. After winding removal, check wire size and turns per coil to see if same as drawing. The stator core must be clean and free of dirt and contamination. This can be achieved by wire brushing the laminations and then wiping. The laminations should be tight. Inspect stator core and remove lumps and sharp edges with a file.

300-E.2.5 REWINDING PROCEDURE. Use data collected in paragraph 300-E.2.4 to set up coil winding machine in shop. Check for pin holes and nicks in magnet wire insulation while winding coils. Discard all defective wire. Wind required number of coils.

1. Measure slot cell width to provide 3/8 inch extension into bore area to act as feeder for magnet wires. Cut slot cell length to provide maximum extension on either end of core (3/8 inch minimum). Check strength of slot material with direction. Use strongest direction parallel to slot length.

2. Cut coil separator to allow 1/4 inch extension beyond slot cell.

3. Cut phase to extend 3/8 inch beyond end turns. This length ensures no cross over of end turns.

4. Cut wedge to the same length as slot cell.

5. Install slot cells with 3/8 inch extension into bore to act as feeder, and with 3/8 inch extension on either end of slot.

6. Feed magnet wire between extension of slot cell being careful that slot cell is not damaged by magnet wire. Make all coil ends even and mark beginning and end of each group.

7. Place coil separator in slot ensuring that no conductor gets around separator and that there is a 1/4 inch extension of coil separator beyond slot cell.

8. Cut slot cell even with the top of slot, lap fold slot cell to form a tube, and place wedge over slot cell and insert until it is even with slot cell.

9. Insert phase until it meets slot cell so that it laps above or below coil separator. Trim phase insulation until it extends 3/8 inch beyond end turns.

10. Scrape insulation from magnet wire ends, place sleeving on wires that are to be joined, and slide sleeving away from joint. Wrap conductors and solder, seal joint with insulating compound or paste, slide sleeving over joint and apply half lapped armor tape over connection area.

11. Mask any bolt holes or machined surfaces to prevent resin contact. Cured resin is difficult to remove.

12. Set up one red devil blower with flexible duct positioned above the stator and an exhaust duct located topside so that any fumes will not reenter the ship through the hatchway.

13. Place stator on flat surface with bore in a vertical position with the lead end down.

14. Electrically energize the conductors, using one-half voltage, to raise the winding temperature to 66° C (150° F). Hold temperature for 1 hour. This will anneal the coils and remove any moisture. Refer to supplier's bulletin for winding temperature during varnishing.

CAUTION

Do not allow large amount of mixed resin (1 quart) to accumulate in drip pan as exothermic reaction of catalyzed resin causes outgasing, with resultant fumes and high temperatures. Separate runoff in small quantities (approximately 1 pint).

15. Thoroughly mix the epoxy components, combine in correct proportions, and mix again for at least 3 minutes. Thorough mixing and correct proportioning is essential.

16. With the windings energized, pour or drip feed the catalyzed resin slowly around the hot windings on the top of the stator until the resin has flowed down through the slot areas and saturated the coils in the bottom position of the windings. (The longer the slot and larger the unit, the lower the temperature should be to assure complete penetration.)

17. Once the slots have been filled, continue to apply resin until the top positioned windings are completely covered and gelled.

NOTE

While pouring the varnish, frequently scrape bore of stator to prevent thick sections of epoxy building up which would require grinding to remove after the varnish has cured.

NOTE

Resin which runs off stator can be collected in a drip pan positioned under the stator and reapplied.

18. Turn the stator over and apply resin to opposite end windings until completely encased. An alternate method is to pour or trickle feed in one direction until completed, then turn the unit over and brush resin on opposite windings.
19. Wipe off any excess resin of the bore.
20. Cure unit in accordance with the technical data sheet for varnish used. A post cure may be necessary to eliminate tacky surfaces on sleeving, tie cord, or metal core parts.

300-E.2.6 HANDLING PRECAUTIONS. Many of the reactive materials used with epoxy resins cause skin irritation to sensitive persons. Avoid contact with the resin and hardener. The use of protective clothing is recommended. If contact occurs, the skin should be washed immediately with mild soap and water. In case of eye contact, flush immediately with water and secure medical attention. Use only well-ventilated areas and avoid prolonged or repeated breathing of the vapors.

300-E.2.7 TEST. After curing is completed, the stator should be given an insulation resistance test both before and after an ac high-potential test. Minimum value of IR should be 200 megohms.

APPENDIX F.

QUALITY ASSURANCE INSPECTION PROCEDURES AND INFORMATION FOR APPLICATION OF INSULATING VARNISHES TO NAVY ELECTRICAL EQUIPMENT

300-F.1 INTRODUCTION

300-F.1.1 GENERAL. To assure high reliability of Navy electrical equipment, the quality of insulation varnishes and the varnish processing must be carefully controlled. Varnish insulating materials are purchased from a supplier as a semi-viscous liquid, used to impregnate and coat electrical equipment, then after a thermal conversion, are delivered to the Navy as a solid insulation material. All varnish materials must meet the requirements of the grade specified for the equipment application according to the classification in MIL-I-24092, **Insulating Varnishes and Solventless Resins for Application by the Dip Process** .

300-F.1.2 VARNISH MANUFACTURER INTERFACE. The varnish manufacturer is notified to include a complete qualification report prior to the actual shipment of the varnish materials. If the varnish supplier is a non-manufacturer such as a manufacturer's representative he also is notified to obtain all the qualification information from the original manufacturer before the actual varnish shipment.

300-F.1.3 STORED VARNISHES. Stored varnishes are slightly reactive and have a tendency to change properties after extended periods at room temperature. Normally this will be noted as an increase in viscosity. If solvent varnishes are permitted to sit without well fitted covers, the solvent will evaporate and also in this case, the viscosity will increase. In either case, if the viscosity increase is significant, two problems can occur. The varnish will not be able to penetrate the small interstices of the electric coils and the build, or coating thickness, will be excessive.

300-F.1.4 CONTAMINATED VARNISHES. Varnishes can also become contaminated. Contamination of liquid varnish can result in poor wetting and produce a rough surface after curing, which readily picks up airborne particles such as carbon dust.

300-F.1.5 VARNISH APPLICATION. Control of the varnish application process is very important. Overcuring the applied varnish can result in a brittle insulation coating the cracks when thermally cycled in service. Conversely, varnish that has not been sufficiently cured can result in an insulation coating with poor moisture resistance.

300-F.1.6 EXCESS SOLVENT. Addition of excess solvent can also cause problems. As the varnish ages (slowly polymerizes) the viscosity is often adjusted by adding solvent. This practice produces a low solids (nonvolatile) content, which can result in a thin coating. Such coatings give less than the required degree of moisture protection (even if fully cured), and will not provide sufficient dielectric insulation.

300-F.1.7 VARNISH FUNCTION. The reliability and useful life of shipboard electrical equipment would be very limited without the addition of the insulating varnish. The insulating varnish has three main functions: it bonds the coils together in the supporting structure; it protects the electrical equipment from hostile environments; it provides a dielectric barrier between points of different voltage potential. The insulating varnish provides these three basic functions only if it is a qualified material and is properly applied. If the materials and the process are not controlled, a defective rotor or stator may have to be completely rebuilt since it is difficult to remove a thoroughly cured varnish without causing considerable damage to the equipment.

300-F.1.8 DESCRIPTION. This appendix provides the Navy inspector with the information required to control the quality of both solvent and solventless varnishes used in processing Navy shipboard equipment. The information and test procedures included in this appendix are specific for the dip and bake varnish process, except where noted otherwise.

300-F.2 QUALITY ASSURANCE INSPECTION PROCEDURES AND INFORMATION

300-F.2.1 CONTROL OF VARNISH RECORDS. The following records shall be made available to the inspector:

Certification to MIL-I-24092

Varnish specification, MIL-I-24092

Technical information package

Instruction sheet

300-F.2.1.1 Certification to MIL-I-24092. As required in MIL-I-24092, the certification shall be signed by a responsible agent of the manufacturer and be included with the qualification and periodic conformance reports. These records shall be examined by the inspector when a new varnish shipment is received. The inspector shall verify that all varnish additions be made with certified materials.

300-F.2.1.2 Varnish Specification, MIL-I-24092. A copy of the latest version of this varnish specification shall be provided for the inspector's use at the varnish treating facility.

300-F.2.1.3 Technical Information Package. A technical information package, supplied by the manufacturer, shall be provided to the inspector.

300-F.2.1.4 Instruction Sheet. A detailed instruction sheet as described in the specification shall also be supplied to the inspector.

300-F.2.2 VARNISH RECORD BOOK. A record book shall be kept for all varnish and process inspections. This is essential for determining the stability of the varnish in the tank. A record of all modifications, fresh varnish additions, solvent additions, tank cleanups, shall be recorded in this record book by the responsible technician. In cases where more than one tank is involved, a separate record book shall be maintained for each varnish tank.

300-F.2.2.1 Varnish Record Book Example. The following is an example of typical varnish data for entry into a record book:

Varnish Tank No. 2

Varnish Identification Poly-varn 22

Varnish Manufacturer ABC Inc. varnish

Classification:

GRADE CB

CLASS 155

COMPOSITION I

RECORD OF ALL CHANGES AND INSPECTIONS (For test methods, refer to MIL-I-24092)

Date	Test	Results	Remarks
x/x/x	Appearance of liquid varnish	_____	Slight cloudiness
x/x/x	Viscosity	350 cps	Increased 5% from last reading
x/x/x	Specific gravity	0.930	No change
x/x/x	Coated test panel, Appearance- Build-	1.1 mils	Small gel particles visible on panel, recommend filtering
x/x/x	Cake hardness Shore D	82	No change
x/x/x	Acetone smear	Passed	No surface tack
x/x/x	Gel time	N/A	(Not required for solvent varnishes)
x/x/x	Thixotropic index	N/A	(Not required for non-thixotropic varnishes)

300-F.2.3 BASIC INSPECTION TESTS. Varnish inspection tests shall be made for any of the following:

a. A new varnish shipment.

b. Before adding stored varnish to the processing tank.

c. For a specific varnish problem.

d. Monitoring the tank varnish every four months.

300-F.2.3.1 Varnish Quality Tests. The following basic tests shall be made to establish the varnish quality:

a. For solvent varnishes and solventless varnishes.
   1 Appearance
   2 Viscosity
   3 Specific gravity
   4 Coated test panel
   5 Build on coated test panel
   6 Cake hardness
   7 Acetone smear test

b. For solventless varnishes only.
   1 Gel time
   2 Thixotropic index

300-F.2.3.2 Appearance. When examined under normal vision the solvent containing varnish or the solventless resin sample shall be free from all foreign substances, such as grit, dirt, oil and water, shall show no signs of phase separation, gel particles or skin formation. Lumps or agglomerates which do not become uniformly part of the compound on mil hand-stirring with a spatula are considered contaminants.

300-F.2.3.2.1 Appearance Requirements. If the conditions of paragraph 300-F.2.3.2 are not satisfied, the Navy equipment cannot be processed with the varnish. An entry shall be made in the varnish record book indicating the specific reason for rejection based on the appearance of the liquid varnish.

300-F.2.3.3 Viscosity. Viscosity is probably the single most important property to measure for quality maintenance. This property determines how well the varnish impregnates the coils and provides a sufficient build of protective coating for the conductors and the entire unit.

300-F.2.3.3.1 Test Method. Determine the viscosity in accordance with ASTM D 2196, **Rheological Properties of Non-Newtonian Materials, Test for.**

300-F.2.3.3.2 Test Instrument. The Brookfield viscometer (Brookfield Engineering Laboratories, Inc.) is the preferred instrument for determining viscosity. The Brookfield viscometer must be calibrated over the range of viscosity of the varnishes to be tested using standard oils traceable to the National Institute of Standards and Technology. A calibration curve showing the relation between viscosity in absolute units and the instrument readings shall be used.

NOTE

If the Brookfield viscometer is used without the guard, it must be restandardized in a suitable container.

300-F.2.3.3.3 Test Procedure. Adjust the temperature of the varnish to 23 ± 1° C. Precautions should be taken to avoid evaporation, or formation of a skin on the surface of the varnish. The test results should be reported in terms of absolute viscosity, in centipoises.

300-F.2.3.3.4 Viscosity Requirements. The viscosity must be within the requirements of the range specified in the individual specification sheets of MIL-I-24092.

300-F.2.3.4 Specific Gravity. Specific gravity is a useful property for controlling the application of varnishes and some resins. It must be realized however that the specific gravity of each batch of varnish must be supplied by the vendor.

300-F.2.3.4.1 Test Method and Procedure. Determine the specific gravity of a representative specimen by measuring the varnish at 23 ± 1° C using a hydrometer with the appropriate range. If a hydrometer is not available this property can be measured using a wide mouth pycnometer (25 ml minimum capacity) at 23 ± 1° C. Refer to ASTM D 1475, **Density of Paint, Varnish, Lacquer, and Related Products, Test for** . Determine the specific gravity by dividing the weight of varnish by the weight of an equal volume of distilled water at the same temperature.

300-F.2.3.4.2 Requirements. The gravity of the tank varnish shall be compared to the manufacturer's value to determine if the tank varnish is within the allowable range according to the periodic conformance requirements of the individual specification sheet of MIL-I-24092. If the material is out of the acceptable range then it must be adjusted before any Navy equipment is processed.

300-F.2.3.5 Appearance of Coated Test Panel. A coated panel specimen provides a means for judging the physical characteristics of the cured varnish. The coated panel is also used to measure build, film cure, and general coating appearance. Coated panels are also conveniently retained for verification purposes or for reference when comparing different varnish conditions. It is recommended that test panels be prepared upon receipt of new varnish and set aside for future comparisons, when quality problems are suspected.

300-F.2.3.5.1 Test Method. Although most varnish manufacturers utilize this test, there is no standard test procedure available. Basically a steel panel is dipped into the varnish specimen, permitted to drain, then cured in an oven. The coating characteristics are then carefully examined.

300-F.2.3.5.2 Materials. A representative specimen of the varnish is slowly transferred to a suitable container (1 quart or 1/2 gallon steel can) to avoid air entrapment. The varnish is permitted to come to equilibrium at 23° C. The steel panels to be dipped into the varnish are type S of ASTM A 366, **Steel, Carbon, Cold-Rolled Sheet, Commercial Quality, Specification for,** 3 x 6 x 0.032 inches, ground one side. The panels are washed in a chlorinated solvent or a suitable substitute, and dried for at least 30 minutes at ambient temperature before coating.

300-F.2.3.5.3 Apparatus. A Fisher-Payne dip coater apparatus is used to control the rate of withdrawing the steel panel from the resin sample at 4 inches per minute. The device is described in ASTM D 823, **Producing Films of Uniform Thickness of Paint, Varnish, Lacquer, and Related Products on Test Panels** .

300-F.2.3.5.4 Procedure. The Fisher-Payne apparatus is first adjusted for a 4 inch per minute rate of withdrawal. The cleaned steel panel is slowly lowered into the varnish, or resin, and is allowed to stand without vibration for 10 to 15 minutes. The panel is then attached to the line on the dip coater apparatus without disturbing the container or the panel. The dip coater is then used to raise the panel out of the varnish. After the panel is free of the varnish surface, the panel is permitted to drain for 30 minutes in a vertical position. The coated panel is then placed in a preheated oven and cured according to the varnish supplier's instruction sheet. Care should be exercised to assure that the coated panel is not vibrated during the draining or early part of the cure cycle.

300-F.2.3.5.5 Requirements. There is no requirement for panel appearance in MIL-I-24092. However, since the panel is generated as a result of the requirement for measuring varnish build, it presents an opportunity to observe the appearance of the cured varnish film.

300-F.2.3.5.6 Appearance Assessment. The appearance of the cured coating reveals whether or not the varnish will provide a smooth, uniform dielectric coating. It is important to look for foreign particles (contamination), varnish gel particles (indicating a stability problem), a tacky surface, poor wetting of the panel, streaks, or any abnormality. The test panel shall be compared to a control panel made from a fresh sample of the certified varnish. If undesirable properties are observed, recommend that appropriate action be taken. For example, if there are particles visible in the coating, have the filter system inspected for proper operation. If there are streaks on the coating, check for a source of contamination such as oil or grease.

300-F.2.3.6 Build on Coated Test Panel. The measure of build or coating thickness on a test panel demonstrates that the varnish produces the required thickness level, for the specific varnish grade, designated on the individual specification sheet of MIL-I-24092.

300-F.2.3.6.1 Test Method and Procedure. The average thickness of the bare panel shall be determined before coating with varnish. After varnish coating and curing, the coating thickness shall be determined on the one inch center width section of the panel steel strip after coating, with the average thickness of the steel panel subtracted and remainder divided by two, shall be taken as the film build per specimen.

300-F.2.3.6.2 Requirements. The varnish build must be within the specification limits as required on the individual specification sheets of MIL-I-24092.

300-F.2.3.7 Cake Hardness Solventless Varnished Only. A small quantity of solventless varnish or resin (20 grams, approximately), is charged to a small weighing dish, then placed in a suitably sized oven to be cured according to the varnish supplier's instructions. The cooled cake is measured for hardness and inspected for uniform properties on the top and bottom surfaces as well as the internal section.

300-F.2.3.7.1 Test Method and Procedure. The hardness measurements shall be made on a cured, cast 1/8 inch thick specimen (approximately) and tested per ASTM D 2240, **Indentation Hardness of Rubber and Plastics by Means of a Durometer, Test for** , using a Shore D instrument. The specimen shall be subjected to the temperature and time specified in the instructions provided by the varnish manufacturer. If the Shore D value is less than that required, a check should be made to make certain that the specimen is cured with the proper temperature and time, as given in the instructions.

300-F.2.3.7.2 Requirements. The varnish shall meet the minimum value required by the individual specification sheets of MIL-I-24092. Hardness shall be determined on the bottom of the cured cake sample. The interior of the cake is also checked for thoroughness of cure by breaking the specimen and examining the cross-section. The overall condition of the cake shall be reported. If the bottom of the cake is very tacky or contains liquid, uncured varnish, the varnish shall not be used for processing Navy equipment. The condition of the interior of the varnish is used only as a means of tracking the varnish curing characteristics. If there is an indication of softness or liquid varnish in the interior of the cake, the varnish supplier should be contacted for assistance.

300-F.2.3.8 Acetone Smear. The acetone smear test is a simple means of determining the extent of cure of a varnish that has already been applied to the electrical equipment. The extent of cure can also be determined by a hardness test on a cured cake as explained in the previous section using a Shore hardness instrument. The Shore hardness test however, is limited to flat surfaces of thick varnish cross-sections. Such flat and thick cross-sections are not usually available on varnished electrical equipment. In this instance the smear test is utilized. The test consists of applying a few drops of acetone to the varnish surface then immediately rubbing the area with a soft cotton cloth over the finger. If the varnish is not thoroughly cured, some of the material will dissolve and can be felt as either a tacky or powdery residue. Alternately the varnish surface will change from glossy to dull. If this occurs, the temperature record of the oven cure cycle should be carefully examined to determine if the equipment was exposed to sufficient heat for the prescribed length of time. Make certain that this time cycle was imposed after the equipment had reached the required temperature according to thermocouples attached directly to the equipment.

300-F.2.3.8.1 Requirements. There are no requirements in MIL-I-24092 for the acetone smear test, however, varnish that does not cure thoroughly shall not be used for processing Navy electrical equipment. If the record shows that the heat input and the time of exposure used for the equipment was correct, and the test shows that the varnish is undercured, the varnish supplier should be contacted for assistance and for specific recommendations. If there is any indication that the heat cycle as insufficient, the equipment should be subjected to an additional bake and the test made again after the unit has cooled to room temperature.

300-F.2.3.9 Gel Time. The gel time of a solventless resin is a measure of the reactivity of the resin, monomer, and catalyst system. If the gel time is too long, an optimum coating will not be achieved because some of the resin ingredients may evaporate in the curing oven before polymerization occurs. It may also result in an inadequate coating thickness since the resin will stay in a liquid state for a longer period of time, and will tend to run off of vertical and inclined surfaces.

300-F.2.3.9.1 Test Method. The gel time shall be measured on three catalyzed resin specimens in accordance with ASTM D 3056, Gel Time of Solventless Varnishes, Test for. A bath temperature of 100, 125 or 150° C shall be employed, and shall be chosen to give a gel time between 10 and 60 minutes.

300-F.2.3.9.2 Test Instrument. The usual gel time instrument is a Sunshine Gel Time Meter and the test procedure is described in the instruction manual supplied by the instrument manufacturer.

300-F.2.3.9.3 Requirements. The gel time shall meet the requirements for periodic conformance as specified in the individual specification sheets of MIL-I-24092.

300-F.2.3.10 Thixotropic Index. The thixotropic index measures the degree of resin retention on the equipment as it is being cured in the oven. A thixotropic solventless resin is used when heavy builds are required. The normal build for a solvent varnish is on the order of 1 mil. Using solventless resins that have been modified for thixotropy, the build may reach 10 to 12 mils. As the tank resin is used, and as it ages, some undesirable changes may occur. With thixotropic materials, resin retention is adversely effected and the thickness of the coating will be less than required. Thixotropy is best measured by comparing the resin viscosity measured at a low speed, to the viscosity measured at a higher speed. The ratio of the low speed to the high speed viscosity yields the thixotropic index.

300-F.2.3.10.1 Test Method and Procedure. The viscosity shall be measured at 23 ± 1° C on catalyzed resin according to method B of ASTM D 2196, **Rheological Properties of Non-Newtonian Materials, Test for** . The viscosity shall be determined at spindle speeds of 2 and 20 rpm. The resin or varnish shall be placed in a 1 quart container to within 1 inch of the top. Using a water bath, adjust the sample to 23 ± 1° C. After reaching the required temperature, wait 90 minutes before the first measurement is made at 2 rpm. The 20 rpm measurement shall then be made immediately after the 2 rpm measurement. Three tests at each speed shall be made to provide an average viscosity value.

The thixotropic index shall be calculated as follows:

$$\text{Thixotropic Index} = \frac{\text{Avg. vis. at 2 rpm}}{\text{Avg. vis. at 20 rpm}}$$

300-F.2.3.10.2 Requirements. The thixotropic index must meet the requirements of the individual specification sheets of MIL-I-24092. The test report shall include: model number of Brookfield viscometer, speed of rotation, spindle number, average viscosity at each speed, and calculated thixotropic index.

300-F.3 BASIC MATERIAL DESCRIPTIONS AND TERMINOLOGY

300-F.3.1 SOLVENT CONTAINING VARNISHES. These are liquid solutions of solid, polymeric materials dissolved in a suitable solvent primarily for application by the dip and bake process. The initial solid, polymeric material is generally an alkyd or modified alkyd and the solvent most often is xylene. Some suppliers refer to the alkyd as a polyester and the modified alkyd as a modified polyester. They may also use the term a **phenolic modified polyester** . In reality, these materials are complex mixtures of compounds of intermediate molecular weight produced by a chemical process know as polyesterification. The solids content generally runs close to 50 percent by weight.

300-F.3.2 SOLVENTLESS POLYESTERS. These resins consists of a solid resin dissolved in a liquid monomer such as vinyl toluene, or DAP (diallyl phthalate). They are referred to as **reactive or unsaturated, polyesters** . They do not contain solvent but monomers which react with the basic resin and become part of the final, cured coating. Solventless resins or varnishes are sometimes referred to as **100% solid materials** . Since there are no solvents to evaporate there is less likelihood of blistering, bubbles, and cavities.

300-F.3.3 SOLVENTLESS EPOXIES. These materials, like the solventless polyesters, contain no solvents. The base material is a high viscosity liquid epoxy. A selective amount of a diluent, which is a low viscosity epoxy, is added to yield the final desired viscosity range. The solventless epoxies have certain properties that distinguish them from the solventless polyesters.

300-F.3.4 OTHER LIQUID POLYMERIC MATERIALS. This category includes materials that, for one reason or another, are not as popular as the materials covered above.

300-F.3.5 POLYBUTADIENES. This class of polymeric material consists of an aliphatic hydrocarbon resin dissolved in a solvent or monomer mixture, usually consisting of naphtha, xylene and/or vinyl toluene.

300-F.3.6 SILICONES. These are resinous materials made from compounds, which in place of the usual carbon backbone, have a backbone of silicon and oxygen atoms. Such a structure offers excellent resistance to oxidation at elevated temperatures. Silicone resins shall not be used on enclosed rotary Navy equipment that operates with carbon brushes since certain silicone vapors can cause severe commutation problems such as excessive brush wear. Solvent solutions of these silicone polymers have been used as varnishes for many years and are recognized for their outstanding long term thermal resistance. However, in recent years they have been replaced with specially modified polyesters which have slightly less thermal stability but offer higher bond strengths at elevated temperatures.

300-F.3.7 PATCHING KITS. These consist of polymeric materials for temporary insulation where damage to the insulation has occurred. Patching kits can be a single component polyurethane varnish, supplied in a can for brush application, or in a pressurized container for spray application. These kits can also consist of a two component epoxy system designed for relatively quick solidification. The latter system, being solventless, may offer an advantage in those instances where toxicity and low flash point are critical.

300-F.3.8 THIXOTROPIC VARNISHES. These are a class of varnish materials in which the flow characteristics have been modified so that the normal build, or coating thickness, is greatly increased. Thixotropy, by definition, is the ability of certain colloidal gels to liquefy when agitated (as by shaking or ultrasonic vibration) and to return to the gel form when at rest. Most electrical varnishes yield a build between 0.5 and 1.2 mils after one dip or treatment. The thixotropic materials will yield 2 to 10 mils, depending on the degree of modification. This special modification is accomplished through the addition of a thixotropic agent which is normally a finely ground mineral filler. This addition is made by the manufacturer but, in some cases, slight additions have been made at the varnish treating facilities to reestablish the original degree of thixotropy. For Navy applications, thixotropic modification has been used only with the solventless type of varnishes and only with the VPI process. There is the possibility in the future that these materials may be used in the dip and bake process.

300-F.3.9 CURED. A varnish or resin must be thoroughly cured or polymerized to achieve its intended purpose. An electrical varnish is designed to provide: mechanical bonding, environmental protection, and a dielectric barrier between points of differing electrical potential. If the varnish has not been adequately polymerized, that is, chemically or thermally reacted from a liquid to a solid state, it will not fully provide these functions.

300-F.4 FUNCTIONAL CONSIDERATIONS

300-F.4.1 SOLVENTLESS VARNISHES. These materials are used primarily when maximum bond strength is required. They also yield a smooth, even coating. Since there is no solvent being removed in the baking process, holes and blisters do not normally form.

300-F.4.2 SOLVENTLESS THIXOTROPIC VARNISHES. The solventless varnishes are more effective when they are modified for thixotropy. This results in a much heavier varnish build per application and effectively increases the total encapsulation. This result in a strong unified coil structure for motors, generators, and motor generator sets.

300-F.4.3 SOLVENT CONTAINING VARNISHES. These varnishes are the general purpose liquid insulation materials used for insulating all types of electrical apparatus for over 35 years. As the solventless materials have become more widely used, the solvent varnishes are now limited to specialized applications such as the finish or top-coat varnish. They are the preferred varnish for overcoating the solventless resin since they yield a very glossy finish. After electrical apparatus has been treated with this type of varnish the solvent immediately begins to evaporate and usually after less than one hour, depending on the temperature and local air movement, they dry to a tack-free coating. At this stage the coating must be baked to achieve its final properties. Once this bake cycle is completed, the varnish coating has a high gloss, and although hard, is capable of absorbing the mechanical and thermal movements necessary for normal equipment performance.

300-F.5 GENERAL VARNISH PROCESSING (VARNISH TREATING)

300-F.5.1 DIP AND BAKE USING A SOLVENT VARNISH. The dip and bake process is the classical method for applying electric varnishes. Normally the varnish used is the solvent containing type. The equipment to be treated is first dried at an elevated temperature and then cooled to between 110° F and 180° F. The specific varnish preheat temperature must be obtained from the **Varnish Instruction Sheet** . While the equipment is at this specified temperature range it is submerged in the varnish which is kept at room temperature. The varnish instructions recommend that the equipment be completely submerged until all bubbling ceases which indicates that all the air has been displaced from the coils. This typically requires 10 to 20 minutes. After this impregnation stage the equipment is held above the tank for drainage, typically 10 to 40 minutes. The unit is then placed in an oven and heated to the final baking temperature. The specific details for the bake cycle are to be given in the manufacturer's instruction sheet.

300-F.5.2 DIP AND BAKE USING A SOLVENTLESS VARNISH. To date the use of solventless varnishes in the dip and bake process has been very limited. It seems likely that this combination will become more commonplace in the future. The basic process should be very similar to the one used for solvent varnishes except that the solventless varnishes require more careful monitoring. This requirement arises because these varnishes or resins contain a catalyst which make them potentially more reactive than the uncatalyzed solvent varnish materials. The solventless resins are best monitored by tracking the viscosity and the gel times.

300-F.6 PROCESS CONTROL FOR DIP AND BAKE PROCESSING

300-F.6.1 EQUIPMENT CLEANLINESS. The various mechanical operations used in the manufacture or refurbishment of electrical equipment are a source of contamination. All loose materials such as filings, grinding scrap, or materials from brazing or cutting operations must be removed. If such materials enter the varnish tank, they will gradually accumulate and be distributed throughout the varnish and may eventually be trapped in the treated, insulated surface. Some varnish facilities include special filters in the processing system to remove contamination. Another method used to avoid airborne contamination is to enclose the equipment scheduled for varnish treatment in polyethylene bags. To check equipment cleanliness prior to the varnish treatment, it is recommended that the various parts of the machine to be varnished be wiped with a clean white cloth wetted with high-flash naphtha, (flash point, 95° C). Evidence of a noticeable amount of dirt on the cloth should be brought to the attention of the processing supervisor. Such equipment must be cleaned before proceeding with the varnish process.

300-F.6.2 TANK MAINTENANCE. The varnish tank should be closed with a properly fitting lid at all times except when equipment is being processed. If the tank is equipped with a cooling system and/or a filtering system, these should be checked for proper operation according to the process equipment specifications. The inside of the tank should be checked occasionally for excessive dried varnish build-up. When varnish samples are taken for inspection, the varnish shall be stirred to obtain a representative specimen.

300-F.6.3 OVEN MAINTENANCE. All ovens used for varnish processing utilize circulating air. These ovens should be cleaned before varnishing the equipment to prevent contamination of the varnish surface. The ovens shall be inspected before the process is started.

300-F.6.4 TEMPERATURE MEASUREMENTS AND RECORDINGS. In addition to the final oven bake there are two steps that require temperature control. The first involves the drying and preheating of the equipment to be varnished. In this step it is important that the unit be heated to the specified temperature for the proper length of time. In the second step the unit is removed from the oven and permitted to cool but only to the temperature level recommended in the supplier's instructions. In both cases the temperature instrumentation should be inspected for proper operation and a record of the time/ temperature cycle shall be made available to the inspector. In the bake cycle it is essential that the time/temperature cycle be accurately measured and recorded. This is especially true in this process step since it normally requires more than one eight-hour work shift. The record must be correct and accurate. The position of the thermocouples should represent the average temperature exposure for the equipment being processed. This control is directly related to achieving or not achieving the optimum cured varnish properties. It should also be recognized that overheating the varnish in this step could result in shortening the useful life of the insulating varnish. If during this step the oven controls fail to restrict excessive temperature, it is possible that the complete insulation system would be decomposed, resulting in a total loss of the equipment.

300-F.6.5 EQUIPMENT HANDLING CAPABILITIES. The condition of the cranes and support stands must be included in the overall approach to maintaining quality. Excessive dirt and poor operation at a critical process time can lead to serious problems. Such equipment shall be inspected before each series of varnish treatments.

300-F.6.6 EQUIPMENT DRYING AND PREHEAT CYCLE. These steps must be carefully controlled. Excessive temperature must be avoided for the equipment that is about to be submerged into the varnish. This is especially true of the solventless varnishes because of their potential reactivity.

APPENDIX G.

SAFETY SUPPLEMENT

300-G.1 STATEMENT OF NEED FOR ELECTRICAL SAFETY

300-G.1.1 GENERAL. At the outset it is to be emphasized that the steel hull of a ship, which is an excellent conductor, and the probable presence of salt water and perspiration, which reduce body resistance, create conditions aboard ship which are more hazardous from the standpoint of electric shock than the conditions which are normally encountered in your homes ashore. For this reason there is a need for better and safer electrical equipment afloat, and more attention to safety precautions.

300-G.1.1.1 Electrical Safety. What is electrical safety? This may sound like a dumb question since everyone knows about the ships' electrical safety program, but not so dumb when you consider the fact that in a 24-month period (06/87 through 05/89) there were 373 cases of electrical shock and several deaths reported to the Naval Safety Center. Also, of 64 formal ships inspection reports reviewed, **only** 17 were unquestionably satisfactory. This difference indicates that the electrical safety atmosphere is severely deficient on many ships. What do these statistics mean? It could indicate that everyone from the top to the bottom in the chain of command should reevaluate their personal involvement in the electrical safety program. Most ships with a satisfactory electrical safety program have one thing in common: they communicate from top to bottom and from bottom to top on safety problems.

300-G.1.1.1.1 Many electrical safety officers have had a chance to grow into their position through many years of electrical experience, but many haven't had the opportunity to gain experience and must depend to a large degree upon the experience of others and the availability of ready sources of information.

300-G.1.1.1.2 The 115-volt circuits and equipment in your homes are usually not considered to be unduly hazardous and, in fact, are not extremely dangerous under most of the conditions existing in your homes. Certain exceptions are well recognized, notably the danger of electric shock to a person who handles electric equipment while in a bathtub. But it seems to be frequently forgotten by personnel afloat:

a. That the conditions existing on naval vessels are quite different from those that exist in your homes ashore and are far more conducive to danger from electric shock.

b. That insofar as danger from electric shock is concerned, the man afloat on a naval vessel is **living in a bathtub** practically all the time.

c. That better equipment and greater safety precautions are needed afloat than ashore to afford equivalent protection against danger from electric shock.

d. That human ingenuity has not yet been able to solve the problem of making electric equipment that will not shock its user when improperly used, and that, therefore, all who have anything to do with electric equipment must give some thought to their own safety and the safety of their shipmates.

300-G.1.2 RECENT STATISTICS OF SHOCK ACCIDENTS. Recent statistics are available to indicate the why of electrical shock accidents and the who. This indicates the reasons for why the various accidents with fatalities happened, and what type of Navy personnel were involved.

300-G.1.2.1 Shipboard Electrical Shock - Its Causes from Recent Statistics. Causes of shock accidents are all focused on human actions or failure to take specific actions. These human reasons are listed below in the order of highest cause:

a. Inattention - 46%

b. Failure to Recognize Hazard - 13%

c. Improper Maintenance - 10%

d. Inadequate Knowledge - 7%

e. Haste - 6%

f. Overconfidence - 5%

g. Equipment Design/Fault - 5%

h. Remaining - 8%

300-G.1.2.1.1 A very large number of the list can focus on the statement:

I DON'T BELIEVE

I COULD BE HURT OR KILLED.

300-G.1.2.1.2 These include Inattention, Failure to Recognize the Hazard, Haste, and Overconfidence, all adding up to 70 percent of the fatal accidents. This black on white reason for accidents is a very direct finger pointing to all levels of Navy personnel who do not believe that accidents can be lethal or will do serious harm.

300-G.1.2.2 Shock Incidents Breakdown. Accidents happen to everybody, and this is indicated by statistics which break down accidents into the grade of Navy personnel injured, and the rates of Navy personnel injured.

300-G.1.2.2.1 By Grade. Navy personnel involved in accidents related to grade of the victim involved are shown in the following list:

a. E1-3 - 21

b. E-4 - 55

c. E-5 - 44

d. E-6 - 14

e. E-7 - 7

f. OFF. - 2

7. Total 141 victims

300-G.1.2.2.1.1 It is expected that accidents are most clustered with those who are expected to be most intimately involved with electrical equipment, systems, cables, etc., i.e., the higher rated and trained seaman. The sum of accidents of the E-4, E-5, and E-6 rates is 113, or 79 percent of the total. Note that the remaining accidents are for lower rates than E-4, E-5, and E-6, and those above. This lower 21 percent are those not so well trained, or those not intimately involved. If the highest percentage of accidents occurs for the highly trained and those closest to the events, then the reasons can be attributed to the simple occurrence of a (a) higher proximity and closeness to the lethal power, and (b) apparent lack a high respect for the lethal potential of the work.

300-G.1.2.2.2 By Rate. An analysis of lethal accidents by rate of the seaman involved indicates that anybody may be involved in a lethal accident. There are more accidents with electrically trained personnel who are closest to the equipment. Other than specifically electric and electronically trained personnel, all other rates of seaman are involved, almost equally. These statistics again point to another outstanding fact:

A LETHAL ELECTRICAL ACCIDENT

MAY HAPPEN TO ANYONE

300-G.2 BASIC CAUSES OF ELECTRIC SHOCK

300-G.2.1 CAUSES. The basic causes of electric shock are:

a. Equipment failure.

b. Human failure.

c. A combination of equipment failure and human failure.

d. A fortuitous combination of events so unlikely and so unusual that even the most prudent of men could hardly be expected to anticipate and guard against it. Accidents of this kind can happen, have happened, and will undoubtedly happen again. Fortunately, however, they are extremely rare.

300-G.2.1.1 Equipment Failure. Although equipment was necessarily involved in each of the fatal accidents, this **does not in itself mean that the accident was caused solely by equipment failure** , or would have happened if there had been no human failure. **Except for one case** , none of the fatal accidents aboard ship was caused by the sudden, unforeseen, and unpredictable failure of approved equipment that had been properly installed, tested for safety after installation, and used in accordance with applicable safety precaution. In the one case that is a possible exception, the insulation resistance of an installation was measured and found satisfactory just one day before an electric shock that killed a man working on the installation. Perhaps the insulation failure that caused the shock occurred before the man started to work on the installation, and could have been detected by another measurement of insulation resistance just before starting to work. Perhaps it did not occur until the man started to work. This case is uncertain. In all other cases, the defect in the equipment could have been found by tests before the fatal accident, or was definitely known to exist before the fatal accident because of minor shocks given by the equipment. But the tests were not made, or the warnings were disregarded, and the defect was not corrected until after the fatal accident occurred. Although there is some uncertainty with respect to the exact number of cases involved in each classification, Table 300-G-1 gives the nature of equipment defects or deficiencies and the approximate number of cases for each classification.

300-G.2.1.2 Human Failures. Human failures or **errors** which were partly or wholly responsible for the 22 shock fatalities aboard ship are listed in Table 300-G-2.

300-G.2.1.2.1 Examples of Human Error. A more detailed consideration of some of the cases will bring out more clearly the errors that led to fatal accidents.

a. In one case, a man sent to repair the control switch for No. 2 rammer motor opened the supply switch marked No. 2 rammer motor, worked on the control switch, reassembled it but left the terminals exposed, had the power turned on to test operation of the control switch, and accidentally came in contact with one of the terminals and was fatally shocked. After the accident it was found that the installation was defective in that the supply switches to No. 1 and No. 2 rammer motors were crisscrossed, No. 1 supply switch feeding No. 2 motor and vice versa. No. 1 supply switch was not opened until after the accident, so that while working on a control switch that he thought was deenergized, the man who was eventually killed was actually working on an energized circuit. His first mistake was in failing to test with a voltmeter or voltage tester to make sure that the switch he intended to work on was deenergized. This mistake, it so happened, was not fatal although it might well have been had the man working on the switch been less fortunate. But the second mistake, failure to avoid contact with a terminal that was known to be alive, was immediately fatal.

b. In another case, a man repaired a portable wire brushing machine, plugged it in to try it out, and was fatally shocked. It was found that in reassembling the tool, a wire in the terminal box had been laid so that one of the threaded cover securing bolts scraped the insulation off, permitting current to flow to the terminal box cover. The plug had been renewed with a light-duty household type plug. The grounding conductor was properly connected in the terminal box, but was not connected to ground at the plug end of the power cable. There were at least three personnel failures in this case:

Table 300-G-1 EQUIPMENT DEFECTS

Defect or Deficiency	Number of Cases
Defects in original installation	7
Defects in equipment after repair aboard ship	4

Table 300-G-2 HUMAN FAILURES OR ERRORS

Failure or Error	Number of Cases
a. Unauthorized modifications to equipment or use of unauthorized equipment	3
b. Failure to observe the necessary safety precautions when using or working on equipment that would be perfectly safe if handled properly. This includes:	
1. Failure to test equipment to make sure that it is deenergized before working on it	2
2. Failure to exercise sufficient care to avoid contact with equipment or conductors that were known to be energized.	13
3. Others	3
c. Failure to make adequate repairs on equipment that has given warning of an unsafe condition by nonfatal shock or shock prior to fatal shock.	2
d. Failure to test equipment for insulation resistance and correctness of ground connection **after making** repairs but**before trying** the equipment for operability or putting it to use.	2
Note that the total number of human failures exceeds the number of fatalities. This is because in some cases more than one error was made.	

1 Failure to use a standard Navy type plug.

2 Failure to make a ground connection.

3 Failure to test the tool for insulation resistance to ground and integrity of ground connection before plugging it in to try it out.

c. In another case involving a portable drill, a man using a drill received two nonfatal shocks before the fatal shock, one in the morning when his hands were bare, and another in the afternoon when wearing a pair of greasy gloves. After the second shock he wore a pair of clean gloves for a time, but ultimately discarded these and was working with bare hands when he picked up the drill late in the afternoon and was fatally shocked. Mistake was piled upon mistake to lead to a fatal conclusion. The first mistake was made by the person who should have tested, but did not test, the drill for insulation resistance and soundness of ground connection before it was put into use. The second mistake was made by the user of the drill when, after receiving a nonfatal shock while working with bare hands, he failed to have the drill repaired and merely put on greasy gloves. The third mistake was made when a nonfatal shock was received while wearing greasy gloves. It was still not too late to fix the drill, but all that seems to have been done was to shift from greasy to clean gloves. And then, finally, one more mistake. The clean gloves were discarded, probably while the drill was not being used, the drill was picked up with bare hands, and a man was killed in an accident that would have been avoided had proper attention been paid to the warnings that preceded it.

d. In another case, a man was killed when he touched a portable submersible bilge pump. The pump had been repaired shortly before, tested without accident, and found to run. But no test had been made to check insulation resistance to ground and correctness of the ground connection. After the accident it was found that phase A of the power supply was connected to the ground terminal on the motor terminal block, and that the grounding conductor was connected to terminal A of the motor. The motor ran when it was tested, but it was nonetheless connected improperly and was deadly.

e. Another accident involved a portable electric grinder. The grinder was correctly connected to the grounded plug on the cord. Unfortunately, however, the user inserted the plug into the receptacle in the wrong position and made a direct metallic connection between one side of the power line and the metal case of the grinder. The plug and receptacle were of an early type (now obsolete) designed to prevent insertion of the plug into the receptacle in any but the correct position. Unfortunately, after the plugs were battered and worn and the polarity pins were broken, or bent, the plug could, by the use of sufficient force, be jammed into the receptacle in the wrong position.

f. In some of these examples, the absence of a correctly made ground connection contributed to a fatal shock. The reasons for using a grounding conductor to make a ground connection, why it is a protection against electric shock when connected correctly, and why it is dangerous when connected incorrectly are considered in some detail later in this text.

300-G.2.1.2.2 Reasons for Human Failure. It is probable that many of the human failures that are responsible for fatal electric shocks on board ships are due to a natural but extremely unfortunate tendency to carry from shore to ship the rather casual regard for the deadly potentialities of electric circuits and equipment that is acquired ashore. The 115-volt circuits and equipment in our homes are usually not considered to be unduly hazardous and, in fact, are not extremely dangerous under most of the conditions existing in our homes. Certain exceptions are well recognized: the largest is the danger of electric shock to a person who handles electric equipment while in a bathtub. Certain conditions regarding shock are forgotten by naval personnel afloat:

a. That the conditions existing on naval vessels are quite different from those that exist in our homes ashore and are far more conducive to danger from electric shock.

b. That insofar as danger from electric shock is concerned, an individual on a naval vessel is **living in a bathtub** practically all the time.

c. That better equipment and greater safety precautions are needed afloat than ashore to afford equivalent protection against danger from electric shock.

d. That human ingenuity has not yet been able to solve the problem of making electric equipment that will not shock its user when improperly used, and that, therefore, all who have anything to do with electric equipment must give some thought to their own safety and the safety of their shipmates.

300-G.3 FUNDAMENTALS OF ELECTRIC SHOCK

300-G.3.1 GENERAL. It is the purpose of the following discussion to point out certain fundamental principles relating to electric shock in order that the need for and the nature of safety precautions may be properly appreciated.

300-G.3.1.1 Shock Intensity. To begin with, current rather than voltage is the proper measurement of the amount of shock intensity. If 60-hertz alternating current is passed through a person from hand to hand or from hand to foot, the effects noted when the current is gradually increased from zero are as follows:

a. At about 1 milliampere (0.001 ampere), the shock is perceptible.

b. At about 10 milliamperes (0.010 ampere), the shock is of sufficient intensity to prevent voluntary control of the muscles and the man may be unable to let go and free himself from the electrodes through which current entered his body.

c. At about 100 milliamperes (0.100 ampere), the shock is fatal if it lasts for 1 second or more.

300-G.3.1.1.1 These figures are approximate only because individuals differ in their resistance to electric shock, but the results of a number of investigations show that the figures given above represent correctly the magnitude of 60-hertz currents that will produce the effects indicated. The same measures that are used to protect personnel from shock by 60-hertz alternating currents should also be used to protect personnel from shock by direct current. Because 60-hertz alternating current is used more extensively than direct current on U.S. naval vessels, the rest of this section will deal with 60-hertz alternating current.

300-G.3.2 BODY RESISTANCE. At the outset of any consideration of safety from electric shock, it is important to recognize that the resistance of the human body cannot be relied upon to prevent a fatal shock from 115-volt or even lower voltage circuits. To be sure, when the skin is dry, it has a high resistance where it makes contact with the electrodes through which current enters and leaves the body. The resistance may be high enough in this case to protect a person from fatal shock even if one hand touches a bare conductor on one side of a 115-volt line while the other hand (or a foot) touches a bare conductor on the other side of the line. But this is an exceptional case. On board a ship, it is far more likely that the skin will be wet with perspiration or salt water. The contact resistance falls when the skin is wet, and the body resistance, measured from electrode to electrode, is low. Tests made by the National Institute of Standards and Technology show that the resistance of the human body may be as low as 300 ohms under unfavorable conditions such as are encountered on naval vessels because of the presence of water and perspiration. If 0.1 ampere is enough to cause death, and if the body resistance can be as low as 300 ohms, it follows immediately that 115-volt circuits can supply more than enough current to be fatal. Mute witness to the correctness of this conclusion is furnished by the graves of people who have been killed by 115-volt and even lower voltage circuits. All circuits, even if of only a few volts, are potentially dangerous in that they may give rise to currents that are immediately fatal, or that keep a person from letting go and ultimately cause death if they are not rescued by their shipmates, or that cause a person to jump and perhaps fall under conditions that will cause serious injury. The resistance of the body itself cannot be relied upon to provide protection from shock.

300-G.3.3 GUARD AGAINST ELECTRIC SHOCK. The application to safety is immediate. To guard against electric shock:

a. A person should, if possible, see to it that his body never forms part of a closed circuit through which current can flow.

b. If this is not possible and it is necessary to include any part of his body in a closed circuit, he should be absolutely sure (1) that the resistance in the circuit is high, (2) that any voltage or difference of potential tending to cause current flow in the circuit is low, or still better, (3) that the resistance is high and the voltage is low. The reasons are obvious. High resistance and low voltage both mean low current. See paragraph 300-2.5 for procedures if it is necessary to work on energized equipment.

300-G.3.3.1 If a person does none of the above and allows his body to form part of a closed circuit in which there is an appreciable voltage and in which the total resistance is low, he will never have another chance. In this connection, it should always be kept in mind that a circuit may be closed by metallic conductors, nonmetallic conductors, or capacitors. A capacitor passes alternating current (and also direct current when the voltage is changing) and does not open a circuit in which it is included even though the plates of opposite polarity are separated by insulation material.

300-G.3.4 CONDITIONS FOR SHOCK. Two conditions must be satisfied for current to flow through a person, namely:

a. The person must form part of a closed circuit in which current can flow.

b. Somewhere in the closed circuit there must be an electromotive force or a difference in potential to cause current flow.

300-G.3.4.1 Touching Power at One Point, Perfectly Isolated. Follow the adventures of Seaman I. R. Drop in his dealings with electric circuits and equipment, and see when he will be in danger of being shocked. First, suppose that Seaman Drop, desiring for some reason to emulate the birds he has seen sitting on electric power transmission lines, swings by one bare hand from a bare conductor on one side of a power line as in Figure 300-G-1. Inspection of the figure shows that Seaman Drop does not form part of a closed circuit. No current can flow through his body, and he will not be shocked even if there is no insulation between his hand and the conductor it grasps. This conclusion does not necessarily hold for high voltage or high frequency circuit, but is valid for 60-hertz, or lower frequency, 115-volt or 450-volt circuits.

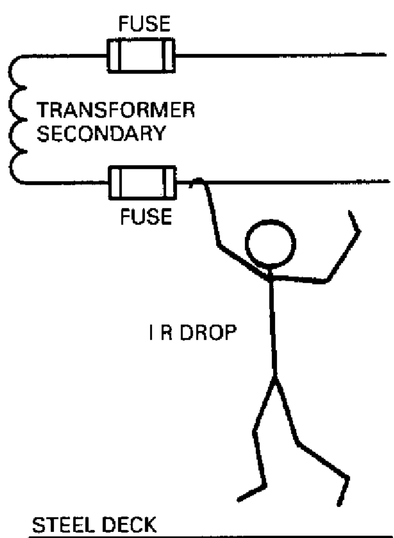


Figure 300-G-1. I. R. Drop Hanging by One Hand

300-G.3.4.2 One Hand Touching Each Power Line. Now suppose that I. R. Drop is foolish enough to reach up with his free hand, also bare, and grasp a bare conductor on the other side of the power line, Figure 300-G-2. Both conditions for current to flow through him are satisfied. He forms a part of a closed circuit through which current can flow from A to B to C to D and back to A, and the power source supplies a voltage causing current to flow. If the power line is a 115-volt or even a lower voltage circuits I. R. Drop will almost certainly be killed. He might survive if he is lucky enough to have dry hands so that they have enough resistance to prevent a fatal shock. Unless he is very lucky indeed, a stunt like this will end his adventure.

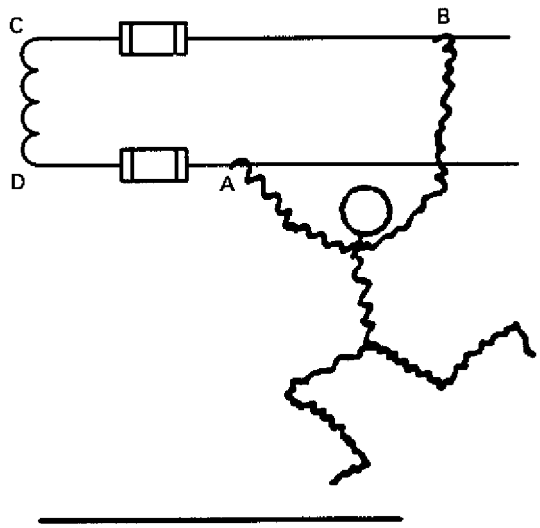


Figure 300-G-2. I. R. Drop Hanging by Two Hands

300-G.4 GROUNDED AND UNGROUNDED SYSTEMS

300-G.4.1 GENERAL. An ungrounded distribution system is one in which there is no intentional metallic or conducting connection from ground (the steel hull) to either line conductor of a two-wire distribution system (ac or dc), or between ground and any line conductor or the neutral of a three-phase ac distribution system, or between ground and either line conductor or the neutral of a three-wire dc distribution system. On United States naval vessels:

a. All ac power and lighting distribution systems, both three-phase and single-phase, are ungrounded.

b. Some polyphase, high voltage ac electric propulsion systems have a neutral which is grounded through a resistor.

c. Most three-wire dc distribution systems are ungrounded.

d. A few three-wire dc distribution systems are grounded with a grounded neutral. These last are the only examples of grounded power and lighting distribution systems in United States naval vessels.

300-G.4.2 TOUCHING THE GROUND SIDE OF A GROUNDED SYSTEM. Take a new I. R. Drop, and for the first of his adventures, suppose that he stands on a steel deck and touches a bare energized conductor of a grounded distribution system. A grounded distribution system is one which is intentionally provided with a solid metallic connection from ground (the steel hull) to one or the other of the two line conductors of a two-wire distribution system, or to one of the line conductors or the neutral of a three-wire dc distribution system, or to one of the line conductors or the neutral of a three-phase ac distribution system. In order to be specific, consider a grounded two-wire ac distribution system, Figure 300-G-3, in which one side is grounded by a metallic connection from C to D.

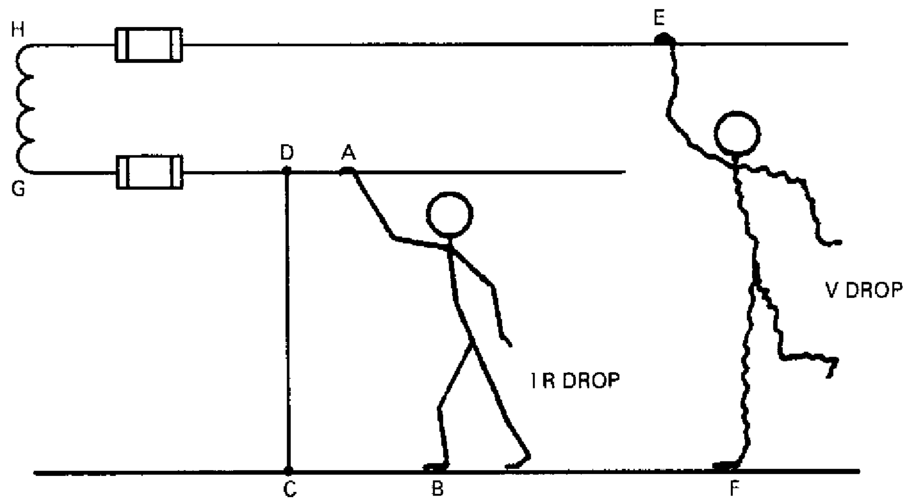


Figure 300-G-3. I. R. Drop and His Brother on Grounded System

300-G.4.2.1 Suppose that I. R. Drop touches the grounded side of the grounded distribution system. He forms part of a closed circuit which runs through his body from A to B and then through metallic conductors from B to C to D and back To A. One of the conditions for current to flow through I. R. Drop is satisfied. The other, however, is not. The closed circuit in which I. R. Drop is connected contains no appreciable voltage to drive current through this circuit. There will be a line drop between D and A if the distribution system is loaded to the right of point A, but the line drop is small and I. R. Drop is in no danger.

300-G.4.2.2 But look at his brother, Seaman V. Drop. He has touched a bare conductor on the ungrounded side of the system. There is a closed circuit through him, E F B C D G H E, and there is a large voltage in this circuit, the full voltage of the power system. In all likelihood I. R. Drop will soon be burying his brother.

300-G.4.3 PERFECT UNGROUNDED SYSTEM. Since almost all distribution systems on naval vessels are ungrounded, let us now suppose that I. R. Drop stands with his foot on the steel deck while with one one bare hand he grasps a bare conductor on one side of a perfect ungrounded distribution system, Figure 300-G-4. By a **perfect** ungrounded system we mean one in which the insulation is perfect on all the cables, switchboards, circuit breakers, receptacles, and other fitting of the distribution system. There are no capacitors in electromagnetic interference (EMI) filters connected from ground to any of the conductors in the system, and there is no way for current to flow to ground, either through conductors, insulators, capacitors, or other means, from any of the conductors in the system. For the sake of having something definite to talk about, consider the specific case of a two-wire, single-phase, ungrounded ac distribution system supplied by power from the secondary of a perfectly insulated transformer so that any grounds there may be on the primary side do not carry over the transformer to the secondary. Refer to Figure 300-G-4. Note that one of the conditions for current to flow through I. R. Drop is not satisfied, namely, he is not part of a closed circuit. His hand at A grasps a bare conductor on one side of the power line, his feet rest on the steel deck at B, but in the perfect ungrounded system we are considering, there is no way in which current can get from ground (the steel deck) back to any point C on the side of the power circuit that he is not holding in his hand. He does not form part of a closed conducting path from one side of the power circuit to the other side. The insulation on the perfect ungrounded system forms a line of defense that protects I. R. Drop from shock.

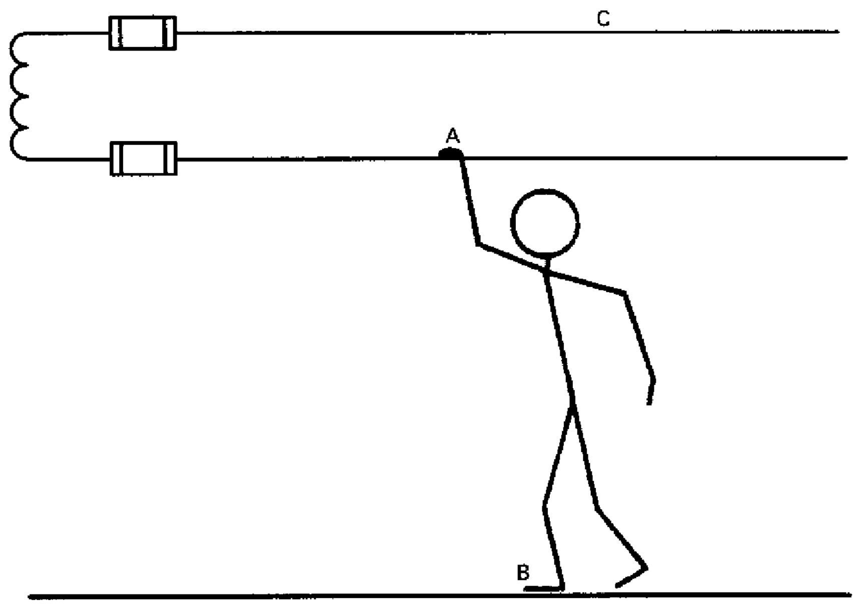


Figure 300-G-4. I. R. Drop and Perfect Ungrounded System

300-G.4.4 REAL UNGROUNDED SYSTEM. **Let it never be assumed that I. R. Drop can safely stand on a steel deck and touch a bare conductor on a real ungrounded system** . He could in the case of the perfect ungrounded system we have just considered, but in the case of a real ungrounded system, he might survive, and then again he might not. There are a number of reasons for this extremely important difference between **perfect** and **real** ungrounded systems. Only four shall be considered:

a. Possible low insulation resistance to ground.

b. Possible presence of poorly designed or improperly installed EMI filters.

c. Possible total **capacitance-to-ground** value (sum of capacitances to ground for cables, connected loads, transformers, EMI filters, and so on) that is large enough to have a low impedance for alternating current and that will, therefore, be a shock hazard.

d. The virtual impossibility of making any tests or check that will establish in advance that it is safe to touch one of the live conductors while standing on the steel deck.

300-G.4.4.1 Low Insulation Resistance. In the case of the perfect ungrounded system, it was the assumed perfect insulation between the live conductors and ground (the steel hull) that formed the line of defense that protected I. R. Drop from shock. In a real ungrounded system this line of defense is formed by real insulation instead of insulation that is assumed to be perfect. Real insulation is not perfect. It is a matter of common knowledge that grounds develop on real ungrounded systems. Except for preventive maintenance, the resistance from the live conductors to ground becomes progressively lower. Water vapor may condense in junction boxes, dirt and dust may accumulate on bare terminals in fittings and fixtures, and insulation may be abraded and broken down. The mere size of a large system is in itself a factor that makes it difficult to maintain high insulation resistance to ground. On a 115-volt system of any size, there will be numerous cables, lighting fixtures, switches, boxes, receptacles, and other fittings. Even though each individually may have a respectable insulation resistance to ground, the combined effect of all is to give a much lower resistance to ground for the entire system. Suppose that the insulation resistance sinks to 300 ohms from each side of the line to ground. This level is much lower than it ought to be, but still not as low as it may be from time to time. Current can then flow from one line conductor to ground through a resistance of 300 ohms, and back to the other line conductor through another resistance of 300 ohms. The resistance from line to line is 300 + 300 or 600 ohms and the line voltage is 115 volts. The leakage current from line to line is, by Ohm's law, about 0.2 amperes. This is too small to overload the source that supplies power to the system, or to interfere with operation of the system. But it is more than enough to kill a person. If I. R. Drop's body resistance is low, as it will be if he is wet with perspiration or salt water, and if he stands on the deck and touches a live conductor on either side of the power line, he will probably be killed. Some of his fellow members of the Navy have been killed in just this way.

300-G.4.4.2 EMI Filters. A second reason for the difference between **perfect** ungrounded systems, in which EMI filters were assumed to be absent, and **real** ungrounded systems is the possible presence of unsafe EMI filters on **real** ungrounded systems. The Bureau of Ships is well aware of the shock hazard created by poorly designed or improperly installed EMI filters, and is working to eliminate this hazard in two different ways. One way is to eliminate electromagnetic interference at its source so that it is not necessary to use any EMI filters at all. The other way is to make sure that only well-designed and safe EMI filters are properly used in those cases where filters are still needed.

300-G.4.4.2.1 In certain types of EMI filters, capacitors are connected from both sides of the power line to ground, see Figure 300-G-5. This figure is not intended to be a circuit diagram of a filter, it is merely intended to show the capacitors connected from the line conductors to ground. Capacitors pass alternating current, and also direct current when the voltage is changing. In a well-designed filter for this application, the capacitors will have voltage ratings high enough to ensure that the insulation will not break down under any voltage to which they may be subjected. Furthermore, the capacitance of the capacitors will be small enough that the current that can pass through the capacitors will be too small to harm I. R. Drop.

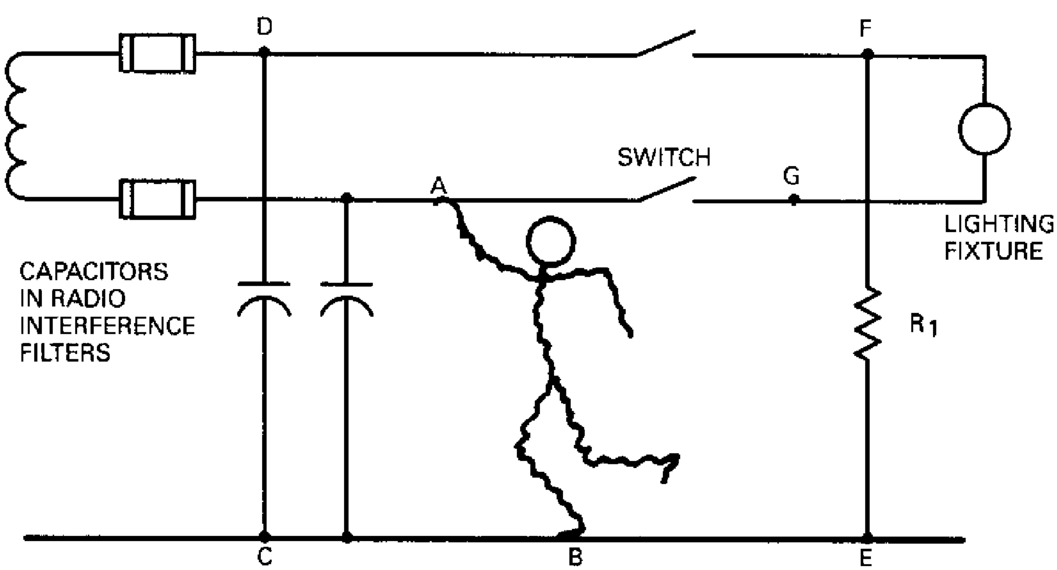


Figure 300-G-5. I. R. Drop and Radio Interference Filters

300-G.4.4.2.2 Things are different with a poorly designed or an improperly installed filter. The capacitors may have a voltage rating not much greater than the 115-volt line voltage so that they break down when a 500-volt megger is used to measure insulation resistance. Even if the insulation is perfect, the value of capacitance may be so high that enough current can flow through the capacitors to kill I. R. Drop.

300-G.4.4.2.3 Consider the case of too much capacitance in more detail. Assume that each of the two capacitors shown in Figure 300-G-5 has a capacitance of 5 microfarads. This is far too much, but no more than has been found in some filters. A capacitance of 5 microfarads has a reactance of 530 ohms at 60 hertz. Suppose that I. R. Drop's body resistance is 800 ohms. Reference to Figure 300-G-5 shows that I. R. Drop's body resistance is connected in series with the reactance of the capacitor in a circuit that goes from one side of the power line at A through B and C to the other side of the line at D. A few moments with vector diagrams and calculations will show that the impedance of the series circuit is 960 ohms and that the current through it, for 115-volts, is 0.12 amperes. This is enough to kill I. R. Drop.

300-G.4.4.2.4 Naturally this filter is not the kind that anyone wants to have on our naval vessels. It is extremely difficult, however, to make absolutely sure that there are none to be found. For this reason, it is no more than common sense to assume that filters like these may still be left, and to take adequate precautions to guard against the possibility of their presence.

300-G.4.4.3 Too Much System Capacitance. A third reason why it is dangerous to stand on a steel deck and touch a live conductor is the possibility of a large value of system capacitance to ground. In all electric power systems there is capacitance to ground from live conductors in cables and connected equipment. The value of capacitance for each foot of cable and for each individual item of equipment is small, but the values add up just as pennies add up to nickels, dimes, and dollars if there are enough of them. In a large system, there are many feet of cable and many individual items of equipment. The total capacitance to ground may be considerable, even if no EMI filters are connected to the system. A large value of capacitance to ground means low impedance for alternating current and danger for I. R. Drop. This danger exists whenever the system capacitance is large, whether the insulation is good or bad.

300-G.4.4.4 Not Knowing If a System Is Safe. Never stand on a steel deck and touch a live conductor. Suppose that I. R. Drop, for obscure and foolish reasons of his own, decides he is going to demonstrate that he can stand with bare feet in a puddle of salt water on a steel deck and touch a live conductor on a real ungrounded system, and do all this without becoming a corpse. Suppose, also, that I. R. Drop, although foolish indeed to have such an idea, is nevertheless not completely foolish and has sense enough to make some tests in advance of his stunt. He carefully deenergizes the 115-volt ac system on which he is going to defy electric shock, uses a voltmeter or voltage tester to make sure it is deenergized and, finding that it is, uses an insulation resistance measuring meter to megger the circuit. The insulation resistance is well up in the megohms.

300-G.4.4.4.1 This looks all right to I. R. Drop. He energizes the circuit and takes up his position with bare feet firmly planted in a puddle of salt water on the steel deck. Just as his finger approaches the bare conductor he is going to touch, doubt assails him. Perhaps he had better make another test. He measures the live conductor he was going to touch with a voltmeter, taking care to avoid a shock as he does this. The voltmeter reads 102 volts. I. R. Drop's knees buckle somewhat as he seats himself on his ditty box to ponder over this unforeseen development. At length it occurs to him that he has seen an EMI filter connected on the system. With pencil and paper, he makes a diagram, and sees how the capacitors in the EMI filter will pass current and give him a reading on a voltmeter connected from line to ground.

300-G.4.4.4.2 He can take care of that. He deenergizes the system again, disconnects the EMI filter, measures the insulation resistance to ground once more, and finds that it is still up in the megohms. He then energizes the system and repeats the voltmeter test from line to ground. This time there is only the tiniest movement of the voltmeter needle. This time he is ready. Somewhat gingerly he touches the bare conductor with the tip of an outstretched finger. Nothing happens. He pushers harder. Still nothing happens. He grasps the conductor firmly in his bare hand. Still nothing happens. A smile of triumph spread over his face. He knew he could do it. And then his face and body are suddenly distorted with pain as electric shock claims still another victim.

300-G.4.4.4.3 How could it happen? Very easily. Refer back to Figure 300-G-5, mentally erase the capacitors in the EMI filter which I. R. Drop disconnected, and look at the switch. This switch is but one of a multitude of switches on the system and I. R. Drop failed to notice that it was open when he made the tests prior to his death. It connects to a lighting fixture that has a low resistance ground, R_1 , from F to E. While I. R. Drop was still triumphantly grasping the bare conductor in his hand, one of his shipmates flipped the switch to have light by which to read a copy of appendix G - Electrical Safety Supplement. That was the end of I. R. Drop.

300-G.4.4.4.4 Of course it did not have to happen that way. The switch might not have been turned on, the low resistance ground might have been on the other side of the lighting fixture, from G to E instead of from F to E, or there might have been no low resistance ground at all. Any of these things would have saved I. R. Drop, and a man who had done a very foolish thing would have lived to tell the tale simply because he was not called upon to pay for his folly. Sometimes individuals don't have to pay, but sometimes they do, and sometimes the price is high.

NOTE

These are four reasons why it is dangerous to stand on a steel deck and touch a bare energized conductor even on an ungrounded system. There are still other reasons, but even one is enough.

300-G.5 PRECAUTIONS

300-G.5.1 BASIC RULES. It should be perfectly clear by now that standing on a steel deck and touching a bare conductor on either a grounded or a real ungrounded distribution system is very much like playing Russian roulette. You pull the trigger and take your chance. If you want to be safe and make sure that your career will not be terminated prematurely by a fatal electric shock, you must:

a. Make sure that you never touch a bare conductor.

b. When the nature of your work is such that it is necessary to touch a bare conductor, then you must either:
   1 Deenergize the conductors on which you are going to work plus all those in the vicinity that you might accidentally touch, and tag these circuits to make sure that they will stay deenergized until you are through with your work; or
   2 If you have to work on live conductors, which sometimes happens, observe the safety precautions that are necessary to protect you from shock.

300-G.5.1.1 These seem like relatively simple things to do. Actually, there are many ways in which you can slip up. It is not possible to consider them all in detail. The best that can be done is to consider a few important points and then emphasize that in the final analysis, it is up to YOUR intelligence to save YOUR life.

300-G.5.2 TOUCHING CONDUCTORS. Avoiding contact with live conductors requires continuous caution and work habits that minimize the possibility of contact. The following are merely two of the things to keep in mind.

300-G.5.2.1 Never use portable cords and other equipment in such a way that a male plug can be energized EXCEPT when it is in a receptacle. The reason is obvious. If the plug is energized when it is not in a receptacle, there is danger of accidental contact with a live terminal. People have died because of this.

300-G.5.2.2 Remember that there are right and wrong ways to rig casualty power to a motor, for example. If you are unwise, you will start by connecting the casualty power cables to the source of power. From then on you will be working with live conductors. It's not invariably fatal, but it is sometimes, and it's very poor practice besides.

300-G.5.2.3 A right way is to start at the motor, disconnect it from its normal source of power and from all alternate sources of power, if it has any, to make sure that the motor cannot be energized by the closing of a circuit breaker not known to you, or by the restoration of power on a circuit that has had a power failure. Observe the same precautions that you would when working on live conductors. Then connect the casualty power from there toward the source of power, making all intermediate connections as you go along. You'll be working with dead conductors all the way. As the last step, make the connection to the source of power. This may have to be made on energized conductors and all necessary precautions should be observed to avoid a shock.

300-G.5.2.4 Another way would be run the cables and make all intermediate connections before those at either end. As the next to the last step, connect to the motor, and as the last step, connect to the source of power.

300-G.5.3 DEENERGIZE AND TAG CIRCUITS. When you must work on bare conductors, and there is no compelling need to keep the power on, deenergize the circuits on which you are going to work and all those in the vicinity that you might accidentally touch, and tag them so that they will not be energized before you are through. Remember that when you open a circuit breaker, you will deenergize the power circuit on the dead side of the breaker, but you will NOT always deenergize associated metering and control circuits. In many cases these are connected to the live side of the circuit breaker and are not affected by opening it. People have died because of overlooking this. Play safe. It may be necessary to pull fuses as well as open circuit breakers or switches to deenergize all the circuits around where you are going to work. Then tagout ALL the circuit breakers and switches you have opened and ALL the fuses you have pulled to make sure that someone else will not inadvertently turn on the power. See paragraph 300-2.4 on tagging procedures. After you think the circuits are deenergized, make sure by testing with a voltmeter or voltage tester. In addition, it would be well to observe the same safety precautions that you would if you were working on live conductors. This practice could be the factor of safety that would save you if you missed one place through which power could be delivered to the conductors on which you are working. On a large system with numerous metering and control circuits, it is difficult to find all these places. It could be that one of the circuits you tested and found to be deenergized was that way only because a circuit breaker or switch happened to be open on a switchboard in another part of the ship. If you have failed to tag it, someone might close it and cause you to be shocked. Remember that your shipmates are not psychic and cannot be expected to know what you are doing. It's up to you to locate all danger spots and tag them, and if you are wise, you will also provide yourself with the back-up protection that comes from working on the conductors as if they were alive.

300-G.5.4 WORKING ON LIVE CONDUCTORS. Sometimes it is necessary to work on conductors when they are alive. This can be done safely if you do it right. Paragraph 300-2.5 gives safety precautions to be observed when working on live conductors. There is no intention to repeat these here, but rather to give the reasons for them. Current cannot flow through your body unless it can get in AND get out. If you work on live conductors with your bare hand, your hand is the point of entry. Remember to wear rubber gloves. Should current enter your body, your safety depends upon seeing to it that there is no point of exit. That's why you must use rubber mats or another suitable insulator to insulate yourself from ground and all metallic or conducting structures connected to ground, and from all conductors on the power line except the one on which you are working. That's why you should use only one hand for the job whenever possible; one hand for the ship, and one hand tucked away in your pocket for you. If you see to it that the current that gets into your body through your working hand cannot get out anywhere, a little consideration will show that your situation is like that of the birds sitting on a transmission line, or I. R. Drop hanging by one hand from one side of a power system. You'll be all right.

300-G.6 PORTABLE ELECTRIC TOOLS

300-G.6.1 EXAMPLES. It is high time to introduce I. R. Drop to portable electric tools and equipment, follow his adventures with them, see how he might be shocked while using them, and study what can be done to promote his safety. Portable electric tools shall be used as representative of the entire class of portable electric equipment and that the tools are used on a 115-volt, single-phase, ac distribution system. Also suppose, as before, that power is supplied by the secondary of a transformer that is perfectly insulated so that any ground on the primary side does not carry across the transformer to the secondary side. The discussion will begin with a tool that is not provided with a grounding conductor. A grounding conductor is a conductor that is entirely separate and distinct from those used to conduct power to the tool, and that is connected to the metal case of a tool at one end and to ground at the other end. The discussion will show that insulation alone, when in good condition, will protect I. R. Drop from electric shock even when no grounding conductor is present. The discussion shall then show that:

a. A grounding conductor, when of proper size and correctly connected, will protect I. R. Drop from shock even in case of insulation failures.
b. A grounding conductor must be of low resistance and adequate current-carrying capacity to do its job.
c. A grounding conductor of high resistance or inadequate current-carrying capacity will not protect I. R. Drop from electric shock.
d. An incorrectly connected grounding conductor will not protect I. R. Drop from shock and may cause him to be fatally shocked.
e. It is, therefore, essential that grounded receptacles on the distribution system, and portable electric tools, their flexible cords, and their plugs be correctly wired. It is also essential that grounded plugs be inserted into grounded receptacles in the right position.

300-G.6.1.1 Perfect Insulation. First suppose that the insulation is perfect on the power distribution system, on the tool, and on the flexible cord; that the total system capacitance to ground is very small; and that no grounding conductor is provided. Conditions will then be as shown in Figure 300-G-6. I. R. Drop is all right in this case. There is no way for current to get from one side of the distribution system to the steel deck on which I. R. Drop stands, and also no way for current to get back to the other side of the distribution system from the metal handle of the tool that I. R. Drop holds in his hands. Hence, no current can flow from I. R. Drop's feet to his hands.

300-G.6.1.1.1 Next, look at I. R. Drop's hands. A closed circuit, which starts at I. R. Drop's right hand, goes through his right and left arms back to his left hand, and through the metal handle back to his right hand. But there is no voltage or potential difference in this circuit to cause current to flow because all parts of the metal case and handle are at the same potential. Similar considerations apply to I. R. Drop's feet. I. R. Drop is perfectly safe in this case. This condition is obviously one to strive for, no difference in potential between any points which I. R. Drop's two hands (or feet) can contact, and perfect insulation of the transformer, cables, and tool.

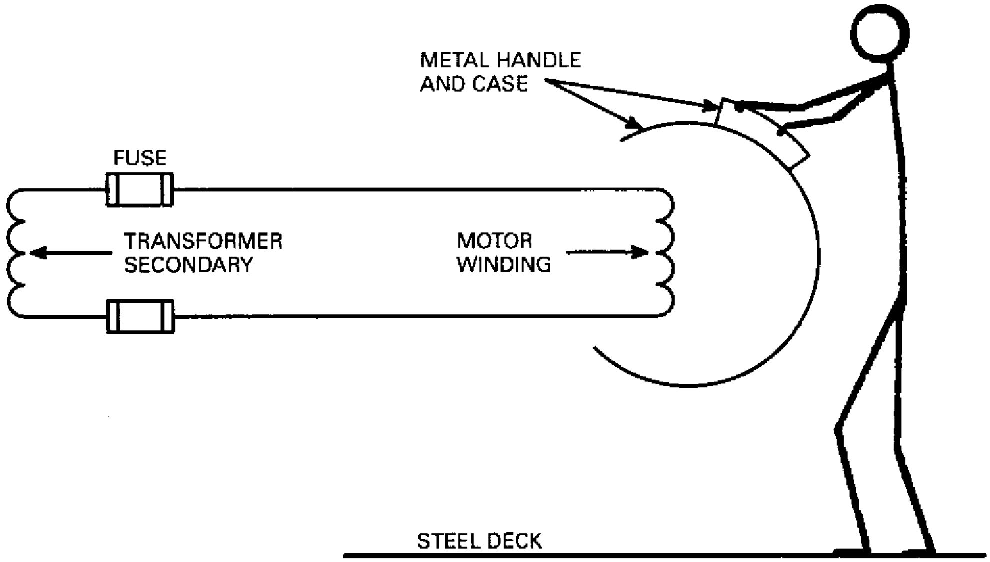


Figure 300-G-6. I. R. Drop and Perfectly Insulated Tool and Distribution System

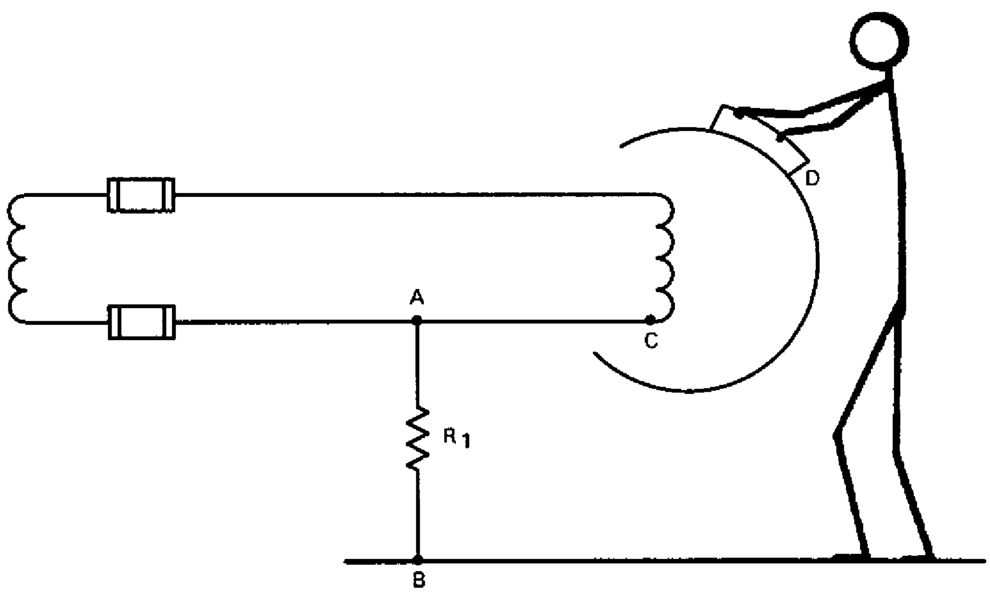


Figure 300-G-7. I. R. Drop and One Insulation Failure, on Line

300-G.6.1.2 One Insulation Failure. Perfect insulation is not possible to maintain under all conditions. It is, therefore, necessary to see what happens when the insulation falls short of perfection. In Figure 300-G-7, suppose that the insulation has failed or deteriorated with the result that there is low insulation resistance, R_1 , between points A and B instead of the extremely high resistance that we would have for perfect insulation. The low resistance, R_1 , may be the result of an insulation failure at point A alone while all the rest of the insulation remains perfect. Alternatively, it may be the result of a multitude of insulation failures spread out all along the side of the power line on which point A is located, none of the individual failures in itself giving very low insulation resistance to ground, but all combining in parallel to give a resultant resistance that is much smaller than that of any of the individual failures. In either case the result is the same, low insulation resistance to ground from one side of the power line. This is considered as one insulation failure without concern over whether the failure is at a single point or a multitude of points.

300-G.6.1.2.1 **Insulation failure** does not mean a complete breakdown of insulation to the extent that the insulation resistance drops to zero. It means a decrease from the high value of good insulation to a much lower value that can be dangerous to personnel. This lower value may be zero in the extreme case, or may be higher, a few hundred or even a thousand ohms. One insulation failure on an ungrounded system will not interfere with its operation. Neither will two failures, even if there is one on each side of the line, unless both are of very low resistance, not more than a few ohms. If the resistance to ground on one side or both sides of the line is a few hundred ohms, the system can still operate even though the insulation resistance is so low that it would be dangerous for a person to stand on the steel deck and touch a live conductor with their bare hand. This point is stressed hereto emphasize that a distribution system may be operating satisfactorily so far as power distribution is concerned but still be dangerous if one of its live conductors is touched.

300-G.6.1.2.2 Now return to Figure 300-G-7 which shows I. R. Drop using a portable tool on a system that has low insulation resistance from one side of the line to ground. Consideration of the figure shows that he will not be shocked even if R_1 is small, a few hundred ohms, or, indeed, even if it is zero. The reason is that I. R. Drop does not form part of a closed circuit. To see this, start from point A. From here there is a current path through R_1 to B, then to I. R. Drop's feet through the steel deck, and through his body, legs, and arms to the handle and the metal case of the tool. But there the path stops. There is no return to A and no current can flow through I. R. Drop this way.

300-G.6.1.2.3 Now look at the circuit that starts where I. R. Drop's right hand grasps the tool handle, runs through his arms to the left hand, and through the handle back to the right hand. This is a closed circuit, but there is no electromotive force to cause current flow since all parts of the tool handle will be at the same potential. Similar considerations apply to I. R. Drop's legs.

300-G.6.1.2.4 In Figure 300-G-8, suppose that the insulation has failed between points C and D, and that the insulation resistance between these points is R_2 . Here again there is no closed current path which includes I. R. Drop and he will not be shocked.

300-G.6.1.2.5 Note that in the case of Figure 300-G-7, the insulation on the tool saved I. R. Drop from shock; in the case of Figure 300-G-8, the insulation on the power line. A grounding conductor was not present in either case.

300-G.6.1.3 Two Insulation Failures. Now suppose, in Figure 300-G-9, that there is an insulation failure between A and B and another between C and D. This time there is a closed current path which includes I. R. Drop's body. It runs from A through R_1 to B, through the steel deck and I. R. Drop to D, through R_2 to C, and finally back to A through the cable between C and A. Furthermore, there is a difference in potential between points A and C to cause current flow in the circuit of which I. R. Drop forms a part. However, this difference in potential is merely the voltage drop in the cable between points A and C and normally will not be greater than about 5 volts.

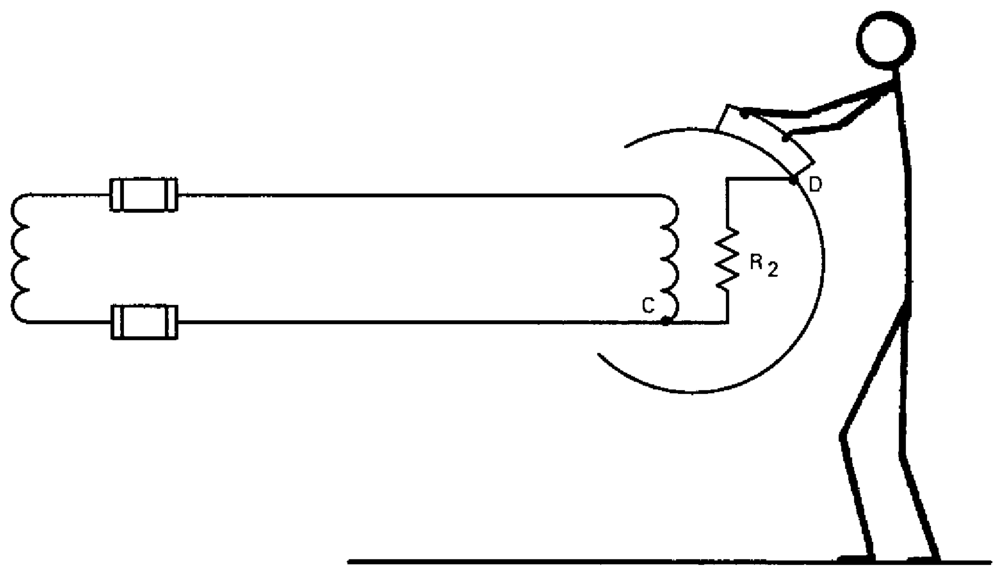


Figure 300-G-8. I. R. Drop and One Insulation Failure, on Tool

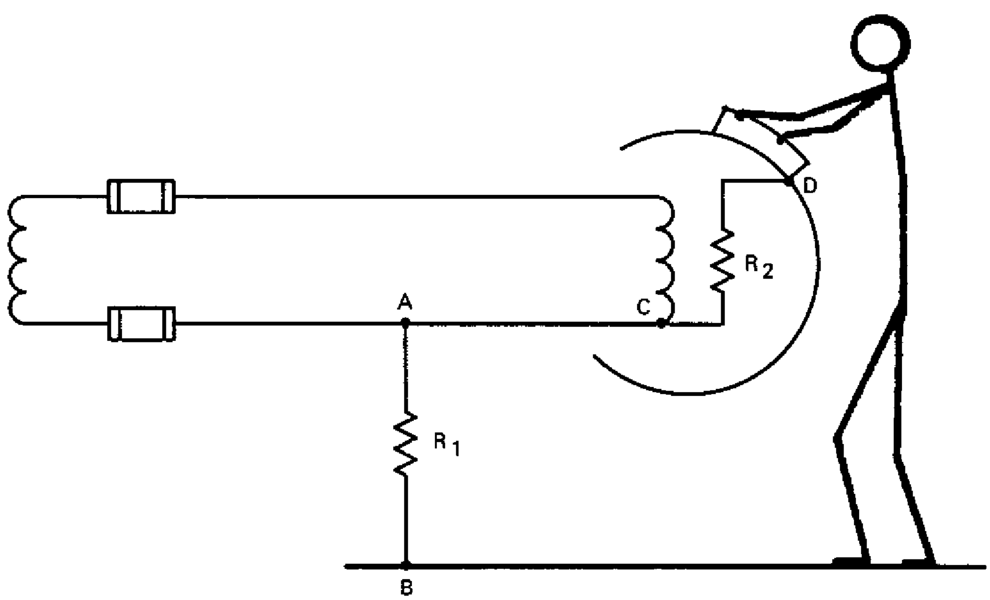


Figure 300-G-9. I. R. Drop and Two Insulation Failures, One on Line and One on Tool

300-G.6.1.3.1 Even if R_1 and R_2 are both zero and I. R. Drop's resistance is only 300 ohms, the current through his body will be only 5/300 or 0.017 amperes. This should not be fatal, but will be enough for I. R. Drop to feel, and conceivably might be enough so that he cannot let go. If this happens, he should lower the tool to the steel deck and ground it by pressing the case against the deck. He should then be able to let go.

300-G.6.1.3.2 Of course, this situation should never arise, for I. R. Drop should have grounded the tool before using it, in accordance with the instructions given later. But, if he has neglected to do so and feels a shock so severe that he cannot let go, he may still be able to lower the tool to the deck on which he is standing and ground it in this way. In any event, whether the tool has a grounding conductor or not, for the conditions illustrated in Figure 300-G-9, I. R. Drop is not likely to receive a fatal shock, and if either of the resistances R_1 or R_2 is several thousand ohms, or if his own resistance is high, he may not receive a shock that can be perceived.

300-G.6.1.3.3 Now look at Figure 300-G-10. The only difference from Figure 300-G-9 is that a circuit between A and C, which was supposed to be closed in Figure 300-G-9, is supposed to be open in Figure 300-G-10 (broken power conductor or loose connection in the tool cord, for example). This difference is enough to be fatal to I. R. Drop. Referring to Figure 300-G-10 , it can be seen that I. R. Drop forms part of a circuit connected to two points A and C, which differ in potential by full line voltage. This situation is entirely different from that in Figure 300-G-9 where the motor consumed practically the entire voltage produced by the transformer secondary, and the potential difference between A and C was only the voltage drop in the cable and connections between points A and C. For the condition shown in Figure 300-G-10, the current through I. R. Drop will be the potential difference between A and C divided by R_1 plus R_2 plus I. R. Drop's resistance. If the total resistance is around a thousand ohms or less, as it may well be if I. R. Drop's hands and feet are wet, the current will be about 0.1 ampere for a 115-volt circuit and in all likelihood will be fatal.

300-G.6.1.3.4 For the next case to consider, see Figure 300-G-11 and suppose that there is an insulation failure between points A and B, and another between points D and E. Here again I. R. Drop is in real trouble, and this time quite regardless of whether the circuit between A and C is open or closed. His own resistance may be only a few hundred ohms, 500 ohms, for example, if he is gripping the tool in sweaty hands and standing on a wet deck, sitting on a wet deck, or bracing a sweaty back against a steel bulkhead. The potential difference between points A and E that will cause current flow through his body is 115 volts, and the current will be 115/ $(500 + R_1 + R_3)$ amperes. If R_1 and R_3 are only a few hundred ohms, it is almost certain that shortly thereafter a board will be convened to investigate the accidental death of I. R. Drop.

300-G.7 THINGS TO BE DONE TO PROTECT AGAINST SHOCK

300-G.7.1 GENERAL. Now, what can be done by the Navy, by I. R. Drop's shipmates, and by I. R. Drop himself to keep this from happening? First, look at the steel hull, water, and perspiration. The steel hull is bad from the standpoint of safety from electric shock because it is an excellent conductor and may form a part of a complete electric circuit which includes I. R. Drop as another part, as in Figure 300-G-10 and Figure 300-G-11. Water and perspiration are bad because they reduce the contact resistance between I. R. Drop and his surroundings.

300-G.7.1.1 Thus, the steel hull, water, and perspiration are all not friendly to safety from electric shock. Nevertheless, nothing can be done about them. Steel ships are here to stay, and it is probable that in the future water and perspiration will be associated with naval life, as in the past. They represent obstacles to safety from electric shock that cannot be removed from naval installations.

300-G.7.1.2 A further question raises: Can anything be done to protect I. R. Drop from shock despite these obstacles? Fortunately, it turns out that something can be done, and even more fortunately that enough can be done to protect I. R. Drop perfectly, PROVIDED THAT THE NECESSARY THINGS ARE DONE. They will do I. R. Drop no good if they are neglected.

300-G.7.2 TWO SAFEGUARDS TO BE SURE OF. There are basically two different things that can be done to prevent the flow of a dangerous current through I. R. Drop when he is connected in an electric circuit. One is to make sure that he is in series with a high resistance. The other is to make sure that there is only a small potential difference to cause current flow.

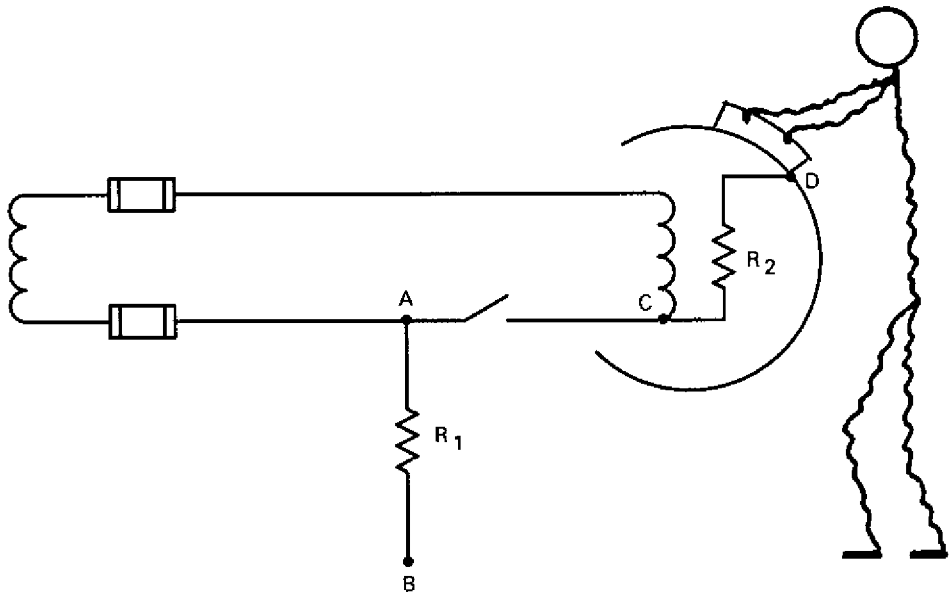


Figure 300-G-10. I. R. Drop Shocked by Broken Lead

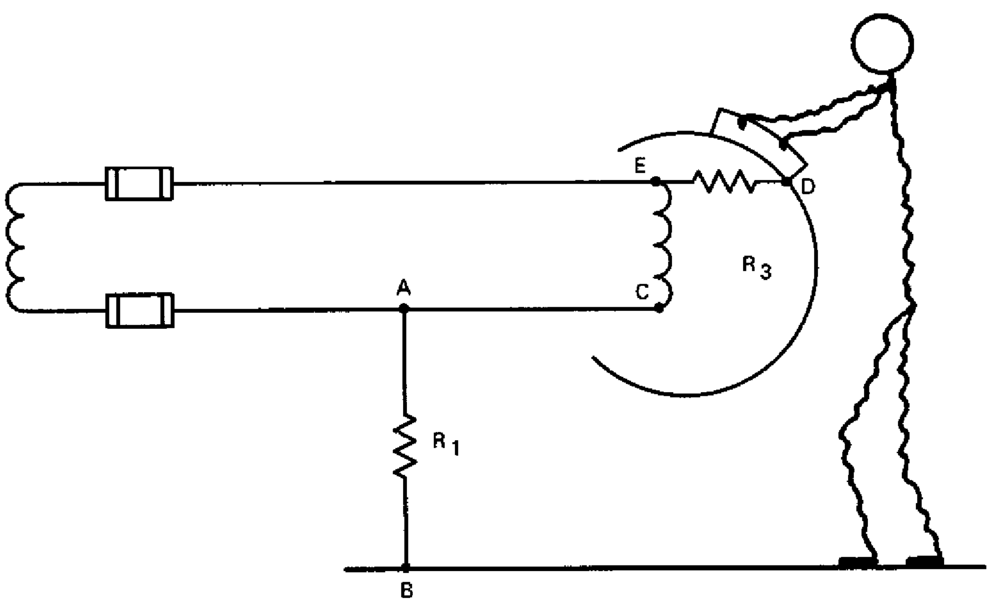


Figure 300-G-11. I. R. Drop Shocked by Two Insulation Failures

300-G.7.2.1 High Resistance. To see the effect of high resistance, refer back to Figure 300-G-11. The current through I. R. Drop is equal to the voltage between points A and E, 115 volts, say, divided by R_1 plus R_3 plus the resistance of I. R. Drop, that is:

$I = 115/(R_1 + R_3 + \text{body resistance})$.

300-G.7.2.1.1 As the National Institute of Standards and Technology tests show, and as numerous fatalities on 115-volt circuits (both afloat and ashore) conclusively prove, the body resistance may be so low that if R_1 and

R_3 are zero or small, the current through I. R. Drop will be enough to kill him. If, however, R_1 is 100,000 ohms, the current will be only 1.1 milliamperes even if R_3 and the body resistance are zero. Similarly, if R_3 is 100,000 ohms, the current will be only 1.1 milliamperes even if R_1 and the body resistance are zero. In either case, I. R. Drop will be protected from a fatal shock, and the protection will be better, the higher R_1 and R_3 are.

300-G.7.2.1.2 R_1 is the insulation resistance from ground (the metal hull of the ship) to one side of the circuit, which supplies power to the tool. All alternating-current power and lighting distribution systems on naval vessels, if constructed in accordance with the General Specifications for Machinery, are ungrounded systems. Present Navy practice is also not to ground the neutral or either leg of three-wire direct-current distribution systems, although a few installations with grounded neutral may be found in older vessels or conversions. In all cases where the system is designed to be ungrounded, R_1 , the insulation resistance to ground, should be kept as high as possible by clearing grounds from circuits and connected equipment. The high insulation resistance so obtained contributes directly to safety from shock. In the few installations with grounded neutral, R_1 will be zero and safety from shock depends upon R_3 and upon the grounding conductor, which is considered later.

300-G.7.2.1.3 R_3 is the insulation resistance from the live conductors in the electric tool to its metal case and handles. This resistance should be measured frequently. The higher the resistance is, the safer the tool will be from the standpoint of safety from shock. An insulation resistance of at least several megohms is to be expected for portable tools. The minimum permissible insulation resistance for portable electric tools and equipment that are to be used on 115-volt circuits is 1 megohm. The minimum permissible insulation resistance for portable electric tools and equipment that are to be used on higher voltage circuits is a resistance such that the line-to-line voltage divided by the insulation resistance gives a current not greater than 0.001 amperes, 1.0 milliampere. Every effort should be made to keep the insulation resistance well above the minimum values.

300-G.7.2.1.4 The maintenance of a high value of resistance for R_1 and R_3 is one measure that will protect I. R. Drop from shock. The other is to make sure that there is only a small difference of potential to cause current flow in the circuit of which I. R. Drop forms a part. A grounding conductor will do this. To see how a grounding conductor protects against shock, refer to Figure 300-G-12. Figure 300-G-12 differs from Figure 300-G-11 by the addition of a grounding conductor between points B and F. This addition makes a big difference to I. R. Drop. In Figure 300-G-11, it was shown that the potential difference causing current flow was the difference in potential between points A and E, or about 115 volts. If I. R. Drop's resistance is 500 ohms, R_1 is 200 ohms, and R_3 is zero, the current through I. R. Drop will be 115/(500 + 200) or 0.16 amperes. This is enough to kill.

300-G.7.2.1.5 Now look at Figure 300-G-12. Suppose that I. R. Drop's resistance is 500 ohms, R_1 is 200 ohms, and R_3 is zero, just as before. Nevertheless, I. R. Drop will be safe provided that the total impedance is low or zero for the metallic path which extends from G (I. R. Drop's feet) through the deck to point B; from B to F through the grounding conductor, and F to D through the metal case. Suppose first that this impedance is zero. Since there can be no difference in potential between points that are separated by zero impedance, the potential of point G will be the same as the potential of the handle of the tool (point D), there will be no potential difference between I. R. Drop's hands and feet, there will be no current through his body, and he will not be shocked. For I. R. Drop, under the conditions just considered, the difference between the presence and absence of a zero impedance grounding conductor means nothing less than the difference between life and death. That is why grounding conductors are important.

300-G.7.2.2 Impedance and Resistance. For practical purposes, the impedance of the metallic path from G through B and F to D can be considered as being very nearly equal to its resistance. It must be remembered, however, that this is permissible only when resistance and impedance are nearly equal and is not valid if someone constructs a very low resistance, but high impedance coil and uses it as the grounding conductor between points B and F of Figure 300-G-12.

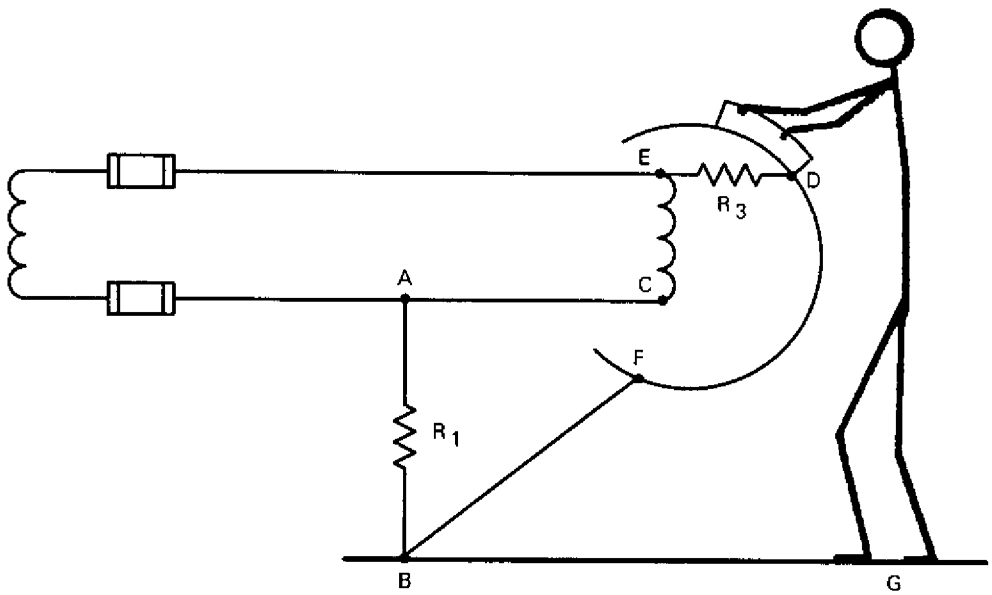


Figure 300-G-12. I. R. Drop Saved by Grounding Conductor

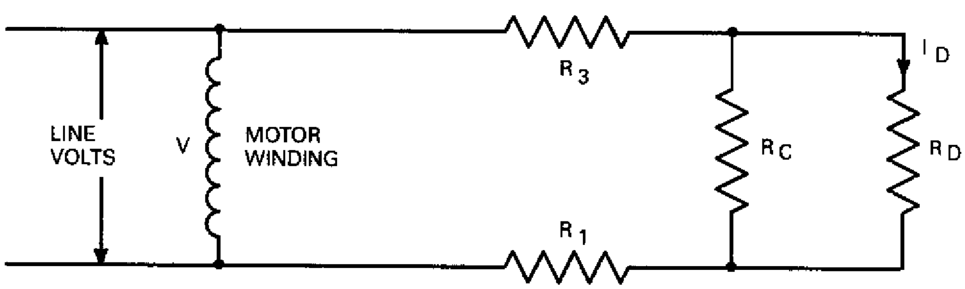


Figure 300-G-13. Simplified Diagram Corresponding to Figure 300-G-12

300-G.7.2.3 Grounding Conductor Resistance. While it is possible to install a low resistance grounding conductor, it is quite impossible to use a zero resistance grounding conductor. It is interesting to look into the effect of finite resistance to see whether a low resistance grounding conductor is really needed. To do this, let R_C denote the resistance of the grounding conductor between points B and F (see Figure 300-G-12) plus the resistance of the metal case between points F and D. Let R_D denote the resistance of I. R. Drop's body from D to G plus the resistance of the steel deck from G to B. The resistance of the metal case of the tool and the resistance of the steel deck are small; consequently, for practical purposes, R_C is the resistance of the ground connection and R_D is the resistance of I. R. Drop's body. Let R_1 and R_3 be the resistances indicated in Figure 300-G-12. The circuit diagram corresponding to Figure 300-G-12 will then be as shown in Figure 300-G-13.

300-G.7.2.3.1 From the circuit diagram of Figure 300-G-13 it is a simple matter to show that the current, ID, which passes through I. R. Drop's body is given by the following expression:

$$I_D = \frac{VR_C}{(R_1 + R_3) R_D + (R_1 + R_3 + R_D) R_C}$$

300-G.7.2.3.2 Furthermore, the potential difference across the circuit that includes I. R. Drop, namely, the potential difference between points B and D of Figure 300-G-12, will be:

$$P.D. = I_D R_D = \frac{VR_C \times R_D}{(R_1 + R_3) R_D + (R_1 + R_3 + R_D) R_C}$$

300-G.7.2.3.3 Now assume that the body resistance, R_D is 500 ohms, that R_1 and R_3 are 200 and zero ohms, respectively, and that V is 115 volts. Then compute ID and the potential difference for different values of R_C , the resistance of the grounding conductor. This gives the values in Table 300-G-3.

300-G.7.2.3.4 Inspection of this table shows a number of things. In the first place, if the resistance of the ground connection is 222 ohms or more, the current through I. R. Drop's body will be equal to 0.1 ampere or more. This is enough to be fatal. To be sure, humans vary in their susceptibility to shock, and there are doubtless some who are lucky enough or rugged enough to survive a current of 0.1 amperes. There are not many, however, who are either lucky enough or rugged enough to survive much more than 0.1 ampere, and it is impossible to be sure that someone will not be killed by even somewhat less current. It can be concluded, therefore, that under the conditions assumed for the preparation of Table 300-G-3, the shock will probably be fatal if the resistance of the grounding conductor is 200 ohms or more.

Table 300-G-3 CURRENT I_D THROUGH I.R. DROP'S BODY

R_C (ohms)	**I_D (amperes)**	**P.D. (volts)**
0.001	0.00000115	0.000575
0.01	0.0000115	0.00575
0.1	0.000115	0.0575
0.87	0.001	0.5
9.3	0.01	5
222	0.1	50
1000	0.14	70

300-G.7.2.3.5 Furthermore, the table shows that if the resistance of the grounding conductor is 9.3 ohms, the current through I. R. Drop will be 0.01 amperes. This is about the limit a person can stand and still be able to let go. Consequently, if a person is caught while working alone, he may not be able to let go and the result may be a fatality even though the current is not enough to cause immediate death.

300-G.7.2.3.6 Nor is this all. If the resistance of the ground connection is 0.87 ohms, the current through I. R. Drop's body is 0.001 amperes. On the basis of present knowledge, this is neither enough to kill nor enough to keep I. R. Drop from releasing his hold upon the tool. However, it is enough to be perceptible. Such a shock, while insufficient to do any direct damage, may nevertheless be fatal to I. R. Drop indirectly by causing him to fall from a ladder, for example.

300-G.7.2.3.7 Consequently, under the conditions assumed for this discussion, the resistance of the ground connection must be less than one ohm to protect I. R. Drop from direct injury by electric shock. Furthermore, it should be very much less than one ohm to provide an ample factor of safety to cover the following contingencies:

a. I. R. Drop may be particularly susceptible to shock and may perceive or be injured by a current smaller than would produce the same effects on other people.

b. I. R. Drop's body resistance may be less than the 500 ohms assumed for this discussion. Remember that the National Institute of Standards and Technology has measured body resistances as low as 300 ohms and that this figure does not necessarily represent an absolute minimum.

c. The insulation resistance R_1 may be lower than the 200 ohm value assumed. To be sure, R_1 and R_3 should both be of the order of hundreds of thousands of ohms, or more, except for grounded systems in which R_1 is zero. But past experience shows that insulation resistances are not always what they should be. A ground connection provides protection against shock when insulation resistances are low, but to do this, the resistance of the ground connection must be very small, the smaller the better.

300-G.7.2.3.8 The last column in Table 300-G-3 shows the potential difference across the circuit in which I. R. Drop is connected. This column shows that for a ground connection of 0.01 ohms resistance, for example, the potential difference across the circuit of which I. R. Drop forms a part is only 0.00575 volts. This is too small to be dangerous. Consequently, one way of looking at the ground connection is that it protects I. R. Drop by preventing the establishment of a large potential difference across the circuit in which I. R. Drop is connected. This means that the current will be small and that I. R. Drop will be protected from shock.

300-G.7.2.3.9 It should be clear from the preceding discussion that the resistance of the ground connection must be low, the lower the better, to afford adequate protection against electric shock. But this alone is not enough. The current-carrying capacity of the ground connection should be high, for if it is too low, I. R. Drop may still receive a fatal shock. To see how this may happen, refer back to Figure 300-G-12 and suppose that the resistance of the grounding conductor, R_C , is 0.04 ohms, that I. R. Drop's resistance, R_D , is 1000 ohms, but that the sum of R_1 and R_3 has fallen to a very low value, 5 ohms, for example. Suppose, further, that the tool is provided either with a double pole switch, which opens both sides of the power line to the left of the motor winding, or with a single pole switch, which opens the upper side of the line to the left of point E. So long as the switch is open, I. R. Drop can hold the tool without receiving an electric shock. Now suppose that he closes the switch to start the motor. The connections will then be as in Figure 300-G-12. A little calculation shows that for a line voltage of 115 volts and resistance values as assumed above, the current through I. R. Drop's body will be about 0.9 milliamperes. This is slightly below the limit of perceptibility and probably will not be perceived by I. R. Drop. So far, the ground connection is affording protection.

300-G.7.2.3.10 What happens thereafter as I. R. Drop continues to use the tool will depend upon the current-carrying capacities of the grounding conductor and the fuses protecting the line that supplies power to the tool. If $R_1 + R_3$ is equal to 5 ohms, the current through the grounding conductor will be 115/5=23 amperes. The current through the fuses will be 23 amperes plus the current taken by the motor plus the current taken by any other devices receiving power from the same circuit. Three things may happen as I. R. Drop uses the tool for an extended period of time. These possibilities are as follows:

a. The fuses may remain intact and the grounding conductor may remain intact. In this case, the current through I. R. Drop will remain at 0.9 milliamperes and he will not be fatally shocked.

b. The fuses may blow while the grounding conductor remains intact. The blowing of either fuses or of both will cut off current through I. R. Drop and protect him from shock.

c. The grounding conductor may burn out while the fuses remain intact. If this happens the conditions in the circuit immediately revert to those illustrated in Figure 300-G-11. The current through I. R. Drop will be 115/(1,000 + 5) = 0.115 amperes and is enough to be fatal. To guard against such an occurrence, the grounding conductor should have sufficient current-carrying capacity to blow the fuses on the line that supplies power for the tool. If the current-carrying capacity is insufficient to do this, the grounding conductor may fail to provide adequate protection.

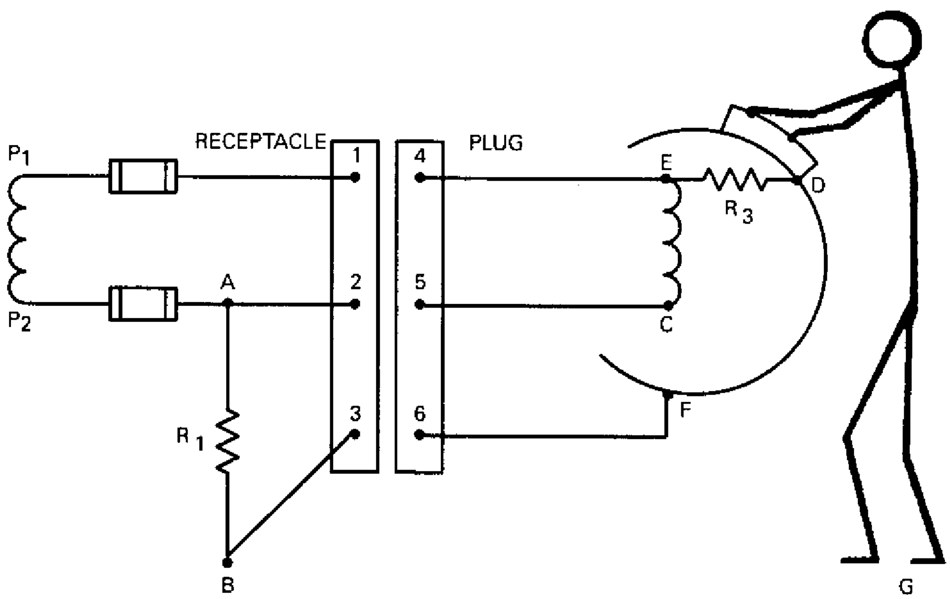


Figure 300-G-14. Schematic Diagram of Grounded Plug and Receptacle

300-G.7.2.3.11 It should be clear from the preceding discussion that when the insulation resistances R_1 and R_3 are high, they will afford adequate protection against electric shock even without a grounding conductor. When the insulation resistances are both low, the entire burden of protecting I. R. Drop from shock is thrown upon the grounding conductor, which must be of low resistance and of ample current-carrying capacity to be effective.

300-G.7.2.3.12 Since the purpose of the grounding conductor is to provide protection when insulation fails, great care should be exercised to make sure that it is of low resistance and of ample current-carrying capacity. Just any wire wrapped around a paint-covered stud or bolt is not enough.

300-G.7.2.4 Grounded Plugs and Receptacles. To facilitate connection of the grounding conductor, installation of grounded-type receptacles has been authorized for all surface ships and submarines. See paragraph 300-2.7.2.1 for grounded type receptacles.

300-G.7.2.4.1 Figure 300-G-14 is a schematic diagram of a grounded plug and receptacle for a two-wire dc or single phase ac power supply. The receptacle has contacts 1 and 2, which are connected to the source of power, and contact 3, which is connected to ground. The plug has contacts 4 and 5, which are connected to the two power conductors in the portable cord and contact 6, which is connected to the grounding conductor that runs to the metal case of the tool at F. Note that the numbers shown on the receptacle and plug contacts and the P_1 and P_2 used to identify the two sides of the power line are added to Figure 300-G-14 and subsequent figures only for convenience of reference, and do not correspond to markings on the plug and receptacle contacts and the power leads in actual installations.

300-G.7.2.4.2 The plug and receptacle are so designed that when the plug is inserted, contact is made first between contacts 3 and 6, thus connecting the grounding conductor before the power supply is connected. When the plug is withdrawn, the power supply is disconnected first, and the grounding conductor last. Thus, with the grounded lugs and receptacles, the grounding conductor is automatically connected first and disconnected last.

300-G.7.2.4.3 Refer now to Figure 300-G-14 and suppose that the plug is inserted into the receptacle making contact between 3 and 6, 2 and 5, and 1 and 4. A little consideration will show that the electrical connections are precisely as in Figure 300-G-12, and that the grounding conductor is connected correctly.

300-G.7.2.4.4 Three conditions MUST be satisfied to ensure that the grounding conductor will be connected correctly, namely:

a. The connections in the receptacle MUST be right.
b. The connections between the flexible cord and the plug at one end, and between the cord and the tool at the other end, MUST be right.
c. The plug MUST be inserted into the receptacle in the right position.

300-G.7.2.4.5 Correct connections are shown in Figure 300-G-14. The essential point about correct connections in the receptacle is that the ground contact, contact 3 in the figure, MUST be connected to ground, point B. If this is done, it is a matter of indifference whether we have:

a. P_1 to 1 and P_2 to 2; or
b. P_1 to 2 and P_2 to 1.

300-G.7.2.4.5.1 Either of these situations is correct. In an installation with numerous receptacles, it is to be expected that some of these receptacles will be connected one way and some the other way. There are four ways of making the receptacle connections incorrectly, as follows:

a. Two ways with B connected to 2, namely
   1 P_1 to 1 and P_2 to 3. to 1.
   2 P_1 to 3 and P_2
b. Two ways with B connected to 1, namely
   1 P_1 to 2 and P_2 to 3.
   2 P_1 to 3 and P_2 to 2.
c. Now assume that the portable cord is connected correctly to both the plug and the tool, that the plug is inserted into the receptacle in the right position, that the insulation on both the system and the tool is in good condition so that R_1 and R_3 can be considered infinite, and that the receptacle is connected incorrectly as shown in Figure 300-G-15. Note that I. R. Drop is connected in series with the motor winding directly across the power

line. The resistance of the motor is small, and if I. R. Drop's body resistance is low, he will be shocked. It has been assumed, for the sake of simplicity, that the insulation is perfect and that R_1 and R_3 are infinite. The same unfortunate consequences for I. R. Drop will follow, however, even if R_1 and R_3 are not infinite, but are high in value, corresponding to good but not perfect insulation.

d. Assume that everything is the same in Figure 300-G-16 as in Figure 300-G-15 except that instead of being infinite or up in the megohms, R_1 is zero, R_3 is 300 ohms, and R_D , I. R. Drop's body resistance, is 500 ohms. Here it is not quite so easy to determine the current paths as in Figure 300-G-15, and it is desirable to draw a simplified diagram corresponding to Figure 300-G-16. Note that since R_1 is assumed to be zero, A and B are at the same potential and can be represented by a single point AB. This gives Figure 300-G-17 as the simplified diagram which corresponds to Figure 300-G-16 for R_1 equal to zero.

e. Reference to Figure 300-G-17 shows that between points D and AB there are two paths in parallel, a 500-ohm resistance through I. R. Drop, and a low resistance path D-F-AB through the grounding conductor. For the sake of having a specific figure to talk about, suppose that the resistance of this path is one ohm. The combined resistance of the two paths in parallel is slightly less than one ohm, which is negligible in comparison with the 300 ohms assumed for R_3 . The current I, through R_3 will be approximately 115/300=0.38 amperes. Of this, only I/501=0.00076 amperes or 0.76 milliamperes will go through I. R. Drop if his resistance is 500 ohms and that of the path D-F-AB is one ohm. I. R. Drop will not be shocked in this case.

f. Note that in Figure 300-G-15 there is a mistake in the receptacle connections combined with perfect insulation on the system and tool. This combination would give I. R. Drop a fatal shock if his body resistance were 500 ohms. In Figure 300-G-16 there is the same mistake in receptacle connections combined with two more mistakes, R_1 equal to zero and R_3 down to 300 ohms. These mistakes add up to leave I. R. Drop unharmed. Of course this is NOT an argument for low insulation resistance. It simply goes to show that here, as in adding a column of figures, one mistake will give a wrong answer, but two or more mistakes may cancel so that the right answer is obtained. But here, also, as in adding a column of figures, the only way to be sure of getting the right answer is to have EVERYTHING RIGHT.

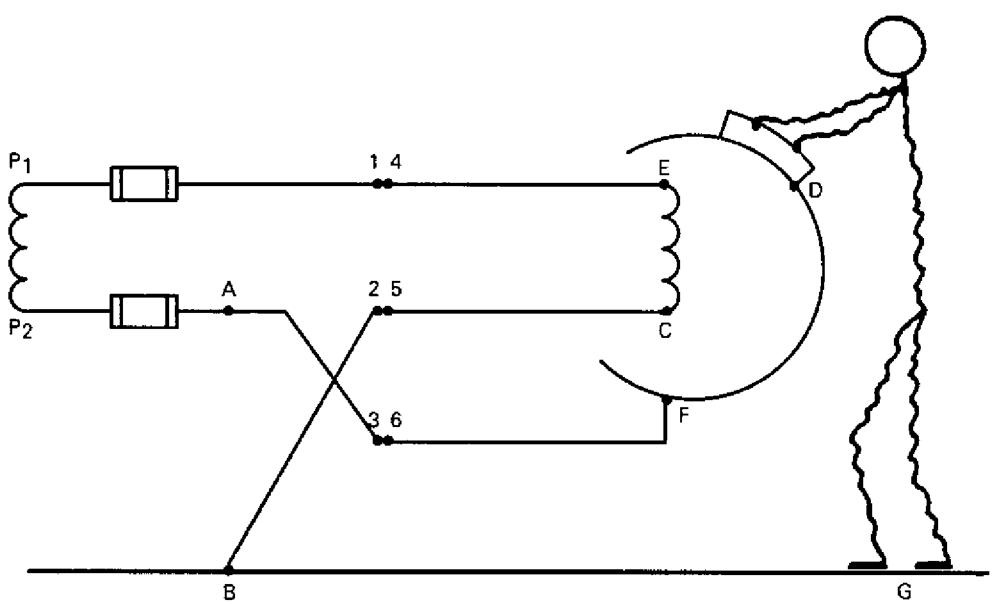


Figure 300-G-15. Wrong Connections in Receptacle, Perfect Insulation on Tool and System

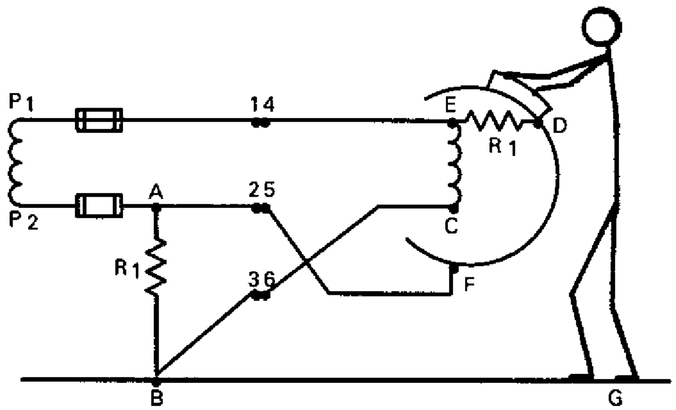


Figure 300-G-16. Wrong Connections in Receptacle, Perfect Insulation on Tool and System

300-G.7.2.4.6 The essential step is to make sure that the ground contact of the plug is connected by the grounding conductor to the metal case of the tool or equipment. An extremely hazardous condition arises if one end of the grounding conductor is connected to the metal case of the tool or equipment and the other end is attached to a plug contact which touches either of the line contacts in the receptacle. Be sure to identify the line contacts and the ground contact correctly, connect the cable to the plug making sure that there are no loose strands of copper that may accidentally connect the grounding conductor to either side of the line, and finally, test the work after the connections have been made, but before inserting the plug in the receptacle. Use a megger or insulation resistance measuring instrument to make this check. With the plug out of the receptacle and with the switch of the tool in the ON position, connect one megger lead to the exposed metal case of the motor equipment and the other megger lead to the ground terminal of the plug. Measure the insulation resistance. It should be zero. Then, with one megger lead still connected to the metal case of the equipment, shift the other megger lead to either line terminal of the plug and measure the resistance. It will be normal insulation resistance (usually well in excess of one megohm) if the ground wire is connected correctly. Repeat with one megger lead still connected to the metal case of the equipment and with the other megger lead connected to the other line terminal of the plug (or to each of the other line terminals if there are more than two). There should be normal insulation resistance in each case if the ground wire is connected correctly. See paragraph 300-2.7.5 for testing of portable equipment. This test should be repeated after a new plug is installed on the tool or equipment after any repair work is done on the equipment or plug, and after a fuse blows on a circuit on which the tool is be infused. The fault that caused the fuse to blow may also have caused the ground connection to burn out.

300-G.7.3 SENSIBLE TESTING. Suppose that I. R. Drop notices a damaged cord on a tool he wants to use, replaces the cord with a new one, connects it to the tool and plug, and then, being lazy, as most of us are inclined to be at times, concludes that a test like that described above is simply too much trouble for him to fool around with. He will do it quick and dirty. Without making any tests at all he puts the plug in a grounded receptacle in the shop and switches the motor on. The tool runs perfectly, so far as he can tell, and he has received no shock at all. He then notices that when he did all this, he was standing in water-soake d shoes in a pool of salt water on an unpainted spot on the steel deck. He realizes that this was a highly stupid thing to do but consoles himself with the thought that **a miss is as good as a mile** , and casually concludes that the tool must surely be all right since it gave him no shock under conditions like these. He hurries off to the place where he is going to use the tool, inserts the plug into a receptacle, flips the switch to **ON** , and is fatally shocked.

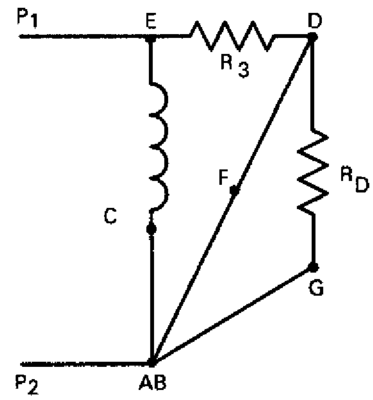


Figure 300-G-17. Simplified Diagram Corresponding to Figure 300-G-18

300-G.7.3.1 Testing. It is worthwhile to see how this could happen. First consider what could have happened when I. R. Drop tried out the tool in the shop. Assume the following:

a. That the receptacle into which he put the plug is wired correctly as shown in Figure 300-G-18.

b. That the flexible cord is connected incorrectly as shown in Figure 300-G-18.

c. That the P_2 side of the power line has a very low resistance ground from A to B which the electricians have not found and cleared, and that R_1 can, therefore, be taken equal to zero.

d. That R_3 , the insulation resistance between the live conductors and the case of the tool, is 300 ohms.

e. That R_D , I. R. Drop's body resistance, is 500 ohms.

f. That the resistances of all the cables and of all the contacts in the receptacle are so small that they can be assumed equal to zero.

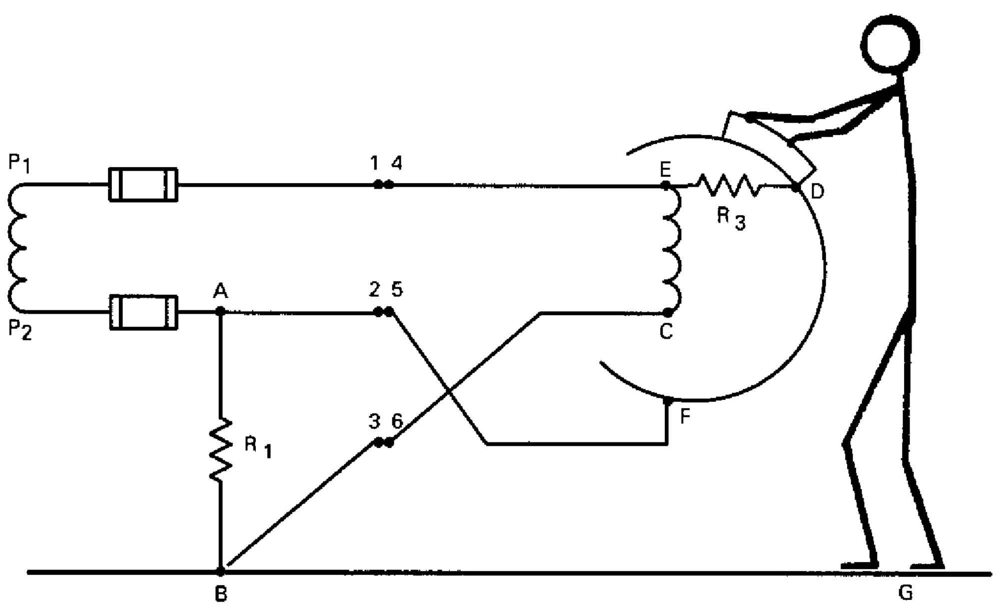


Figure 300-G-18. Conditions at Trial in Shop

300-G.7.3.1.1 A little consideration will show that when the plug is inserted into the receptacles, the connections will be as shown in Figure 300-G-17, which we considered previously. Note that the motor is connected directly across the line and will run. Note also that I. R. Drop is in parallel with the low resistance path D-F-AB which carries most of the current that goes through R_3 and leaves only a fraction of a milliampere to go through I. R. Drop, as we have seen in the previous discussion of Figure 300-G-18. In the shop test, therefore, the motor will run and I. R. Drop will not be shocked. This is why I. R. Drop erroneously concludes that everything is all right.

300-G.7.3.2 Testing Tools in Use. Now suppose that when I. R. Drop puts the tool to use, everything is just the same as when he tried it in the shop except that the receptacle is connected as shown in Figure 300-G-19 instead of as in Figure 300-G-18.

300-G.7.3.2.1 As pointed out before, the receptacle connections shown in Figure 300-G-18 and Figure 300-G-19 are both correct. Some receptacles will be connected one way, some the other. Suppose that I. R. Drop hit the kind shown in Figure 300-G-18 when he tried the tool in the shop, and that he hits the kind shown in Figure 300-G-19 when he puts the tool to use. From Figure 300-G-19 a simplified diagram is shown in Figure 300-G-20 in which R_1 is assumed to be zero. Again a single point AB instead of two points A and B is used.

300-G.7.3.2.2 Reference to Figure 300-G-20 shows that the motor will not run. But this is not the worst. I. R. Drop is connected directly across the power line. To be sure, his 500-ohm body resistance is connected in parallel with the 300-ohm resistance between D and AB. This, however, does him no good. The potential difference across him is 115 volts, his resistance is 500 ohms, and the current through him is 0.230 amperes or 230 milliamperes. This is more than enough to kill.

300-G.7.3.2.3 The moral of all this should be clear. You can NEVER assume that a portable tool is safe simply because you have tried it, found that it runs, and has not shocked you. The tool could kill you the next time you try it. If I. R. Drop had taken a few minutes after he changed the cord and had tested it in accordance with the paragraph on CORRECT CORD CONNECTIONS, he would have found:

a. That the cord connections were wrong, and

b. That the insulation resistance from the live conductors to the case of the tool was only 300 ohms.

300-G.7.3.2.3.1 He should never have used a tool with an insulation resistance so low. Even if he had been foolish enough to do this, but had changed the cord connections to make them right, the grounding conductor would have saved him. But he assumed instead that his quick and dirty trial proved that everything was all right. This killed him.

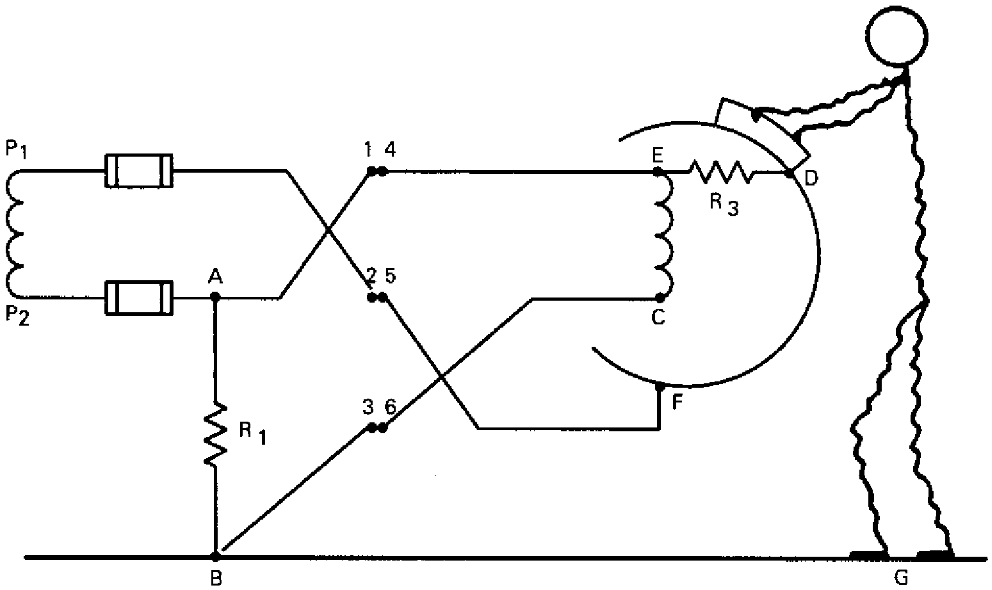


Figure 300-G-19. Conditions with Tool in Use

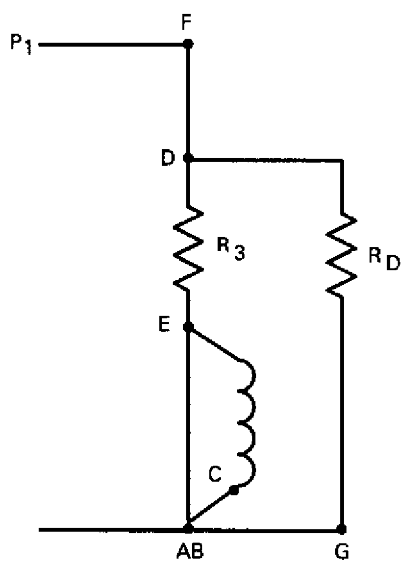


Figure 300-G-20. Simplified Diagram Corresponding to 300-G-19

300-G.7.4 TESTING PORTABLE EQUIPMENT. Portable electric tools and equipment should be tested periodically to make sure that they are maintained in good condition. For periodic testing of portable equipment, see paragraph 300-2.7.5.2.1. Two acceptable tagging methods for approved equipment can be found in paragraph 300-2.7.3.6.2.

300-G.7.4.1 Proper Plug Positions. The connections in the receptacle and to the cord must be right to protect I. R. Drop from shock. So, too, must the position of the plug be right when it is inserted into the receptacle.

300-G.7.4.1.1 Grounded plugs and receptacles are designed with the objective of making it impossible to insert the plug in any position except the right position, but to do this requires the cooperation of personnel who use the equipment. Make sure that the covers of the receptacle boxes are assembled correctly to guide the plug in the right position. Then don't force a plug into a receptacle when it does not want to go. Perhaps you can succeed, and perhaps it will kill you when you use the tool.

300-G.7.5 THREE LINES OF DEFENSE. Summarizing the results, when I. R. Drop is using a portable tool on an ungrounded system, assuming all connections are correct and that the plug is inserted in the right position, there are three lines of defense that protect I. R. Drop from shock. These are:

a. The insulation on the distribution system.

b. The insulation on the tool and cord.

c. The grounding conductor.

Each of these three lines of defense, if it holds, is enough to save I. R. Drop from a fatal shock. The following paragraphs describe them in more detail.

300-G.7.5.1 The First Line of Defense. The first line of defense is the insulation on the power distribution system. The weakness of this line is that it covers a lot of territory, is spread thin as a consequence, and can be breached in a number of ways, such as by insulation failure, by poorly designed or improperly used EMI filters, by a large value of system capacitance, by the closing of a switch to connect ground detector lamps or voltmeters if either are installed, or in other ways which may not be obvious. Furthermore, as described before, it is extremely difficult and perhaps impossible to make a test which will establish with certainty whether this line of defense is intact or not. For these reasons, the first line of defense CANNOT be depended upon to protect you from a fatal electric shock. This does not mean, however, that the first line of defense is to be despised. Every effort should be made to maintain it by keeping the insulation resistance to ground as high as possible. This line of defense has undoubtedly saved many a person's life in the past and will undoubtedly save many a person's life in the future. However, you gamble with death when you assume that this line of defense alone will save you from a fatal shock.

300-G.7.5.2 The Second Line of Defense. The second line of defense is the insulation between the live conductors and the metal case of portable electric tools and equipment. This is a concentrated line of defense. It is all in the tool and its cord and plug. It can be tested to determine whether it is sound or whether a hole has been punched in it. It should be considered the main line of defense.

300-G.7.5.3 The Third Line of Defense. The third line of defense is the grounding conductor. If the grounding conductor is of low resistance and adequate current carrying capacity, if the grounded receptacles and plugs are connected correctly, and if the plug is inserted into the receptacle in the right position, then the grounding conductor will save I. R. Drop from a fatal shock even after the other two lines of defense have failed. The third line is the last gasp line of defense. Note that when the second or main line of defense is maintained intact by keeping the tool insulation resistance high, something which should always be done, the grounding conductor has nothing to do. It provides a safety factor and is something like the safety grips that keep an elevator from falling if the cables break.

300-G.8 CONCLUSION

300-G.8.1 SUMMARY. This section does no more than begin to consider all the different ways in which a person can be killed by electric shock. There are many possible combinations of events which can lead to a fatal shock. The important things to keep in mind are:

a. If you do things in the wrong way when dealing with electric circuits and equipment:

   1 Some fortuitous combination of circumstances may save you from a fatal shock; or

   2 A different combination of circumstances may kill you.

b. If you do things in the right way in dealing with electric circuits and equipment, you will be safe.

300-G.8.2 Navsea Concern. NAVSEA is vitally interested in providing the safest possible electric equipment for use by personnel on U.S. Navy ships. But neither NAVSEA nor any other organization can protect you from electric shock. NAVSEA can help you in various ways, but in the final analysis, you and your shipmates must do the job. It is a job well worth doing. It may be tiresome to study about safety, it may be unpleasant to devote the time and effort that are necessary to ensure safety, but it is far better to be safe from electric shock than to become I. R. Drop, deceased, or to have one of your shipmates become I. R. Drop, deceased.

APPENDIX H.

ELECTRICAL/ELECTRONIC WORKBENCHES

300-H.1 INTRODUCTION

300-H.1.1 GENERAL. Electrical/electronic workbenches are used to work on energized electrical and electronic equipment. They are used individually and in workshops such as Electrical Repair, AIMD, Electronics, Avionics, and Calibration. Personnel safety is of primary concern during maintenance on energized equipment. The workbenches are insulated from the top working surface and below to reduce the shock hazard to maintenance personnel.

300-H.1.2 Grounding Requirements. Metal workbenches shall be grounded to the hull and have equipment grounding leads. See Figure 300-H-1.

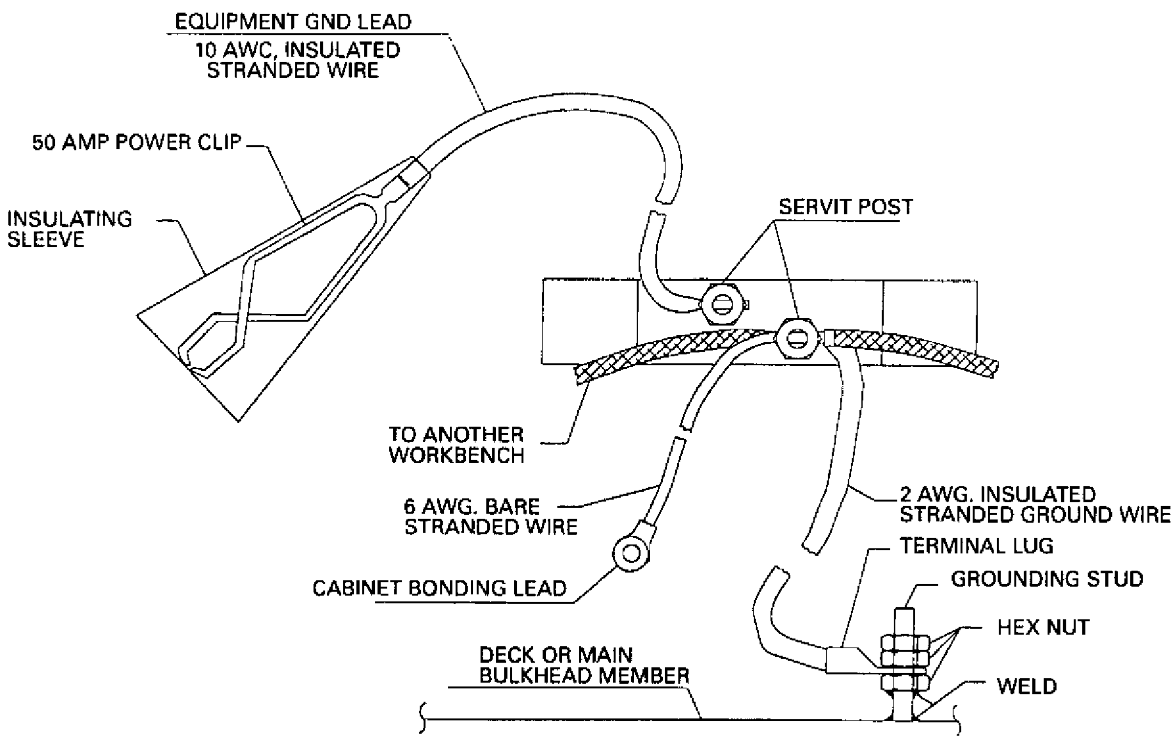


Figure 300-H-1. Workbench Grounding

a. Grounding studs shall be welded to the hull, if feasible, or to main members of the bulkhead. The ground stud connection shall be cleaned bright metal to metal to ensure electrical continuity. The ground wire shall be an insulated, stranded wire, size 2 AWG (green color insulation or marked with green colored tape or green colored adhesive labels), connected to the grounding stud. After the ground wire is installed, the grounding stud connection shall be painted the same color as the surrounding structure to prevent moisture penetration. In existing installation, the ground wire can be other than green in color or designation. If the ground wire is replaced it shall be replaced with a wire insulation green in color or designation.

b. The workbench nearest the center of a row of workbenches shall be grounded by the ground wire from the lower servit post of the workbench center cabinet to a grounding stud.

c. A ground bus serving a row of workbenches shall be continuous (unspliced) cable not to exceed 50 feet in length. The ground bus shall be insulated, stranded wire, size 2 AWG (green color insulation or marked with green colored tape or green colored adhesive labels). The cable shall pass through the lower servit post of each grounding bracket.

d. Each workbench section (cabinet, back panel, shelf and auxiliary table) shall be bonded to ground potential using bare, stranded wire, size 6 AWG bonding lead. The cable shall pass through the lower servit post of the grounding bracket.

e. Equipment ground and servit post connections shall be cleaned bright metal to metal. After ground and bonding cables are installed, connections shall be sealed with two coats of varnish (TT-V-119) to prevent moisture penetration. Resistance from the workbench metal structure to the hull shall be less than or equal to 0.1 ohms. In existing installations, the ground wire can be other than bare, green in color or designation. If the ground wire is replaced it shall be replaced with a bare wire or wire insulation green in color or designation.

f. The ground wire shall be installed between the assemblies and the terminal block in such a manner that vibration, expansion, contraction, or relative movement, incident to normal shipboard operations, will not break or loosen the ground wire connection.

g. Equipment grounding leads shall be provided for each four (4) feet of workbench installed. Grounding leads (green color insulation or green designation on the wire), shall be stranded wire, size 10 AWG. The minimum length is 40 inches with a 50 ampere blunt nose battery type clip and insulating sleeve at the free end. Grounding leads shall be connected to the servit posts. Servit posts must be clean before connecting grounding leads. Servit posts are sealed with two coats of varnish (TT-V-119). Resistance from the ground clip to a point beside the deck grounding stud shall be less than or equal to 0.1 ohms. In existing installations, the equipment grounding lead wire can be other than green in color or designation. If the equipment grounding lead wire is replaced, it shall be replaced with a wire green in color or designation.

300-H.1.3 Insulation. Electrical/Electronic workbenches are insulated from the top working surface to the deck. On some ships, surfaces above the top working surface, metal structures and objects adjoining the workbench and within the reach of the technician, may be insulated. This is acceptable but is not required. Insulation materials above the top working surface or around the workbench shall be kept in good condition or removed if damaged. The deck in front of the workbenches shall be covered with electrical grade matting. See Figure 300-H-2 and Figure 300-H-3.

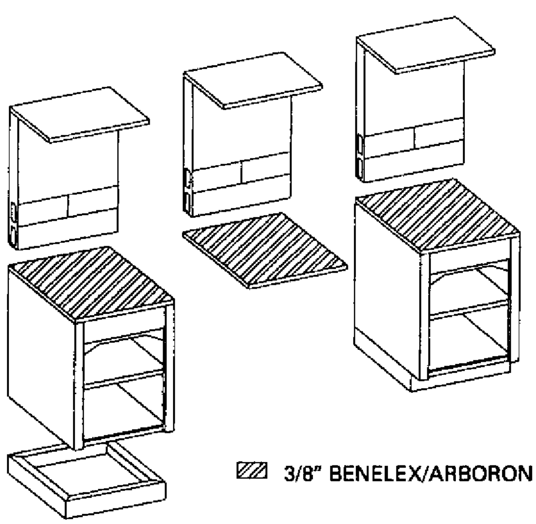


Figure 300-H-2. Insulation

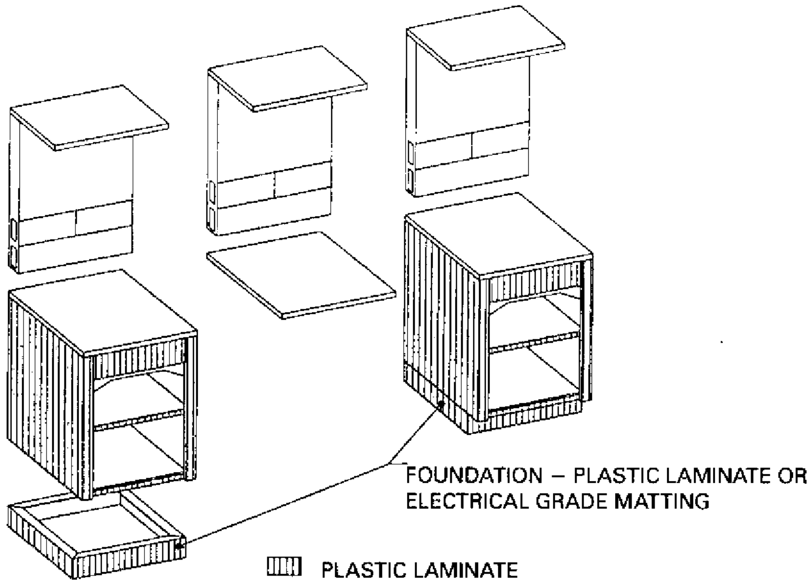


Figure 300-H-3. Insulation

300-H.1.3.1 Top Working Surface. The working surface insulation shall be either 3/8 inch Benelex 401 (a dark brown material) or Arboron secured to the support surface with 1/4-20 nylon screws. Some ships have a laminate working surface that is glued to the top substructure and this is acceptable.

a. **Inspection and repair** . The insulation material shall be intact with no damage, cracks or joint separation that exposes underlying metal. If insulation is damaged or missing, replace with recommended manufacturers material. Benelex is no longer manufactured. Arboron is a commercial, one for one, substitute for Benelex. Arboron is available from AIN Plastics (Comm 1-800-431-2451). AIN has local offices throughout the USA. Another supplier is Western Slate Co (Comm 1-800-541-1251). These are not the only sources of Arboron. Suppliers that carried Benelex will probably carry Arboron. Check locally for other suppliers.

300-H.1.3.2 Exposed Metal Surfaces Below The Top Working Surface. Exposed metal surface below the top working surface shall be insulated with plastic laminate in accordance with MIL-P-15037, 1/32 inches to 1/8 inches thick. Drawer front surfaces and other exposed metal surface on existing workbenches may be covered with Benelex 401 and this is acceptable. The surfaces to be covered are:

a. front surfaces of cabinet and auxiliary table.

b. knee surfaces under auxiliary table.

c. drawer fronts.

d. foundations (these may be covered with electrical grade matting - see paragraph H.1.3.4 below).

300-H.1.3.3 Shelf Area. The insides of the drawers need not be covered. They are to remain closed while working on energized equipment. The shelf area beneath the drawer is normally open on the standard workbench. An alternative to insulating the fronts of the shelves is to install a door over the opening. The door shall be Benelex, Arboron or other non-conductive material. It shall be attached with nylon or other nonconductive hardware. Drawing 53711-613-6054897 provides details for one type of door and hardware.

a. **Inspection and repair.** Inspect exposed surfaces from the top working surface to the deck. The insulation material shall be intact with no cracks, fraying or joint separation that exposes underlying metal. If insulation is damaged or missing, replace with recommended similar material, manufacturers material or MIL-I-24768/1 plastic laminate, 1/32 inch to 1/8 inch thick. The foundation may be covered with plastic laminate or electrical grade matting. Some fleet installations use Benelex on some surfaces; this material is acceptable.

300-H.1.3.4 Surrounding Deck Area. The object is to prevent persons working or observing at the workbench from providing a path to ground through the deck. Electrical grade sheet deck covering conforming to MIL-M-15562, Type 1, shall be installed in front of insulated workbenches, in any kneehole, and if either end of the workbench is accessible to personnel, cover the deck at the end(s) of the workbench. No seams shall be within 3 feet of electrical/electronic workbenches. If this is unavoidable, seams shall be heat welded or chemically sealed to provide a continuous surface free of seams, craters or porosities.

a. **Inspection and repair.** Ensure safety matting is attached to deck. Inspect matting for wear and fraying. Inspect seams. If matting is damaged or missing replace with MIL-M-15662, Type 1, material.

300-H.1.3.5 Attaching Metal Objects To Workbench Surfaces. Do not defeat the purpose of the insulation by attaching vices, locks, hasps, metal tie downs, or other metal hardware to the metal workbench through the insulation.

300-H.2 CUTTING AND DRILLING INSTRUCTIONS FOR BENELEX 401 AND ARBORON

300-H.2.1 CIRCULAR SAWS. A tungsten carbide tipped circular saw blade is recommended for cutting Benelex and Arboron products. A saw speed of 5000 fpm should be used and the blade should penetrate 1-1/4″ to 1-1/2″. The following feed rates should be used in cutting the various thickness of Benelex and Arboron with tungsten carbide tipped blades.

THICKNESS	RATE OF FEED
1/4″ to 1/2″	25 - 30 fpm
1/2″ to 1″	18 - 20 fpm

300-H.2.1.1 A hollow ground high-speed, metal cutting circular saw blade may be used for limited production cutting.

300-H.2.2 BAND SAWS. Metal cutting type band saws can be used in straight and contour cutting of Benelex and Arboron. These saws are hardened on the tooth edge only and cannot be resharpened. Another type of band saw suitable for production cutting is the Skip or Buttress Tooth type blade. This is used for rapid cutting where a rough edge is allowable.

300-H.2.2.1 Standard saw blades of 20 gauge with 4 to 6 teeth per inch and a Rockwell hardness of 60c to 62c are usually operated at 1500 to 2000 fpm when cutting Benelex or Arboron.

300-H.2.3 DRILL HOLES. Holes should always be drilled in Benelex and Arboron when mechanical fasteners are used. DO NOT attempt to drive screws, nails or similar fasteners into Benelex or Arboron. For maximum holding power with various taps, use recommended pilot hole sizes as shown below:

SCREW and TAP SIZE	1/8	3/16	1/4	5/16	3/8	1/2	5/8
BIT SIZE	3/32	5/32	7/32	1/4	5/16	13/32	1/2

300-H.2.4 DRILLING. Benelex and Arboron may be drilled with high speed or tungsten carbide tipped drill bits. Carbon steel bits are not satisfactory as they require frequent resharpening. Benelex and Arboron should be backed up with a hard material to give smooth holes, free from burrs and chipped edges. In drilling parallel to the laminations, Benelex and Arboron should be clamped to reduce the possibility of delamination.

300-H.2.4.1 High Speed Bits. The 18 degree helix bit gives the best results in drilling Benelex or Arboron. Its wide polished flutes provide free cutting action and good chip removal preventing chip packing and overheating. This type of bit should be ground with a 60 to 80 degree point angle, a 10 to 15 degree clearance angle, and a 125 to 135 degree chisel edge angle. The quality of the hole obtained in Benelex and Arboron is dependent on the drill speed and rate of feed. Best results are obtained with drill speeds of 400 to 800 rpm when used with feed rates of 0.015 to 0.020 inches per revolution.

300-H.2.4.2 Tungsten Carbide Tipped Bits. Benelex and Arboron should be drilled with a 12 degree spiral tungsten carbide tipped bit operated at approximately 180 fpm. Bits should be machine fed whenever possible. This will ensure more accurate and smoother holes. If hand feeding is necessary, backing off the lips of the bit will prevent it from grabbing. Holes approximately 0.002 inches smaller than the diameter of the bit will be obtained when drilling Benelex and Arboron with bits having accurately ground points. Grinding the bit slightly off center will produce holes equal to the diameter of the bit.

300-H.3 ELECTRICAL POWER CONNECTIONS

300-H.3.1 In order to minimize the electrical shock hazard and possible damage to equipment and ships power distribution system, all 120-volt, 60 hertz, single phase receptacle connectors (such as workbench receptacles) shall be the grounded type connected to single-phase circuits through isolating transformers on the basis of the following principles:

a. Circuits supplying receptacle connectors shall not supply other types of loads.

b. Isolating transformers shall be either 450/120-volt or 120/120-volt.

c. The minimum size transformer shall be 3kVA.

d. Each receptacle circuit shall be separately protected.

e. No more than 15-receptacle connectors shall be connected to a receptacle circuit. However, more than one receptacle circuit may be supplied by a single transformer.

300-H.3.2 Only approved power receptacles shall be used with electrical and electronic workbenches. Multiple receptacle panels and Electric Power Outlet Panels (EPOP), shall be installed (when needed) on the electrical/ electronic workbench backpanel, on a bulkhead or in a convenient location so special power is readily available for testing equipment. The approved types are symbol numbers 754.2 (MIL-P-22438/1B), 755.3 (MIL-P-22438/ 2B) and panels (EPOP II) built in accordance with NAEC drawings 63A114F12 and 63A114J14. The 120-volt, 60 hertz power shall be provided as above, 400 hertz and DC shall be provided from 400 hertz and dc power panels.

300-H.4 ELECTRICAL POWER DISCONNECT SWITCHES

300-H.4.1 DISCONNECT SWITCHES. Power disconnect switches shall be provided to quickly disconnect workbench power (60Hz, 400Hz, DC). The disconnect switch(es) shall not be located on the workbench. Three basic types of disconnect circuits exist in the fleet. Type 1. One switch (pushbutton station) disconnects all power (60Hz, 400Hz, DC) to all workbench EPOPs and electrical receptacles and test switchboards. In large workshops, multiple disconnect switches are wired so activation of any switch secures all power to all workbenches and test switchboards. Type 2. Individual switches disconnect 60 Hz power, 400 Hz power and DC. Type 3. Circuit breakers in power panels disconnect power to workbench EPOPs and receptacles and test switchboards. Some ships may have combinations of two or more types.

a. Type 1, PREFERRED METHOD. A power disconnect switch (pushbutton station) shall be located just inside the access to the space. The switch shall disconnect ALL power (60Hz, 400Hz, DC) to workbench EPOPs and electrical receptacles. The pushbutton station (switch) shall be visible to personnel entering the space, readily accessible to safety observers and clearly identify which workbench(es) the pushbutton (switch) controls. The bulkhead mounted pushbutton station shall be located 48 to 54 inches above the deck, within a red-painted target. The pushbutton shall not be part of the normal protection devices for the workbench.

b. Type 2. In large workshops, multiple disconnect pushbuttons (switches) shall be wired so activation of any pushbutton (switch) will secure ALL power (60Hz, 400Hz DC) to ALL workbenches.

c. Type 3. Power panels (60Hz, 400Hz, DC) installed in the same compartment as the workbenches, may be used as workbench power disconnects. The circuit breaker(s) inside the power panel(s) shall be clearly marked with a red target around them for easy identification. They shall be clearly marked as to which workbench(es) they control. If the power panel is in an adjacent compartment or is not readily accessible to the individual at the workbench, or a second party, a power disconnect switch (pushbutton station) shall be located just inside the access to the space (see paragraph 300-H.4a above).

300-H.4.2 WORKBENCHES AND TEST SWITCHBOARDS. Power for electrical/electronic workbenches and electrical test switchboards in the same compartment shall be controlled by the same power disconnect switch(es).

300-H.5 SIGNS AND LABEL PLATES.

a. Above the electrical/electronic workbenches used for working on energized equipment post this sign.

b.

DANGER
ELECTRICAL SHOCK HAZARD
DO NOT TOUCH ENERGIZED CIRCUITS

THIS IS AN ELECTRICALLY SAFE WORKBENCH

b. Above workbenches that are ONLY USED TO WORK ON UNENERGIZED ELECTRICAL EQUIPMENT post this sign.

d.

DANGER **WORKING ON ENERGIZED ELECTRICAL EQUIPMENT IS PROHIBITED ON THIS WORKBENCH** **THIS IS NOT AN ELECTRICALLY SAFE WORKBENCH**

c. Near the workbench post the following signs giving the approved method of rescuing personnel in contact with energized circuits.

f. and

DANGER **DO NOT ATTEMPT TO ADMINISTER FIRST AID OR COME INTO PHYSICAL CONTACT WITH AN ELECTRIC SHOCK VICTIM BEFORE THE POWER IS SHUT OFF**

DANGER **REMOVAL OF PERSONNEL IN CONTACT WITH ENERGIZED ELECTRICAL CIRCUITS** **DO NOT TRY TO REMOVE VICTIM WITH YOUR BARE HANDS** **1. DE-ENERGIZE THE CIRCUIT IF POSSIBLE** **2. IF CIRCUIT CANNOT BE DE-ENERGIZED:** **– YOU MUST INSULATE YOURSELF FROM HIS ENTIRE BODY BY USING A NON-CONDUCTOR TO PUSH HIM FREE ON THE CONTACT** **– IF YOU ARE IN CONTACT WITH A LIVE CIRCUIT AND NO ONE IS NEARBY TO HELP, TRY TO BREAK THE CONTACT BY THROWING YOUR BODY.**

d. Adjacent to the workbench post Cardiopulmonary Resuscitation Placard NSN-0177-LF-008-1700 and the WARNING sign NSN-0177-LF-008-1200.

e. Post this label plate near the emergency cut-off switch(es).

i.

FOR EMERGENCY USE ONLY

WORKBENCH DISCONNECT SWITCH

All parts and components, except receptacle panels Sym 754.2, EPOP-II and Sym 755.3, are common items that are available locally in metropolitan areas.

Table 300-H-1 (PART 1) SELECTED WORKBENCH PARTS AND COMPONENTS

PART/COMPONENT	NSN
BENELEX 401 3/8″	5970-01-030-2607
ARBORON 3/8″	COMMERCIAL ITEM
PLASTIC LAMINATE	COMMERCIAL ITEM
CLIP, POWER 50 AMP	5999-00-195-9676
INSULATING SLEEVE FOR POWER CLIP	5975-00-281-0024
STUD, WELDING 3/8″ X 2″	5307-00-265-9152
LUG SOLDER TYPE	5940-00-115-0775
SERVIT POST 1/4-20	5940-00-177-2680
LUG FOR D-10 WIRE	5940-00-114-1300
RECEPTACLE PANEL, EPOP, SIX OUTLET	
SYMBOL 754. 2	6110-00-889-0990
RECEPTACLE PANEL, EPOP-II, EIGHT OUTLET	6110-00-839-8026
RECEPTACLE PANEL, EIGHT OUTLET, SYM 755.3	6110-00-091-9436
1/4-20 NYLON SCREW 3/4″	5305-00-543-5733
1/4-20 NYLON SCREW 7/8″	5305-01-133-4457
1/4-20 NYLON SCREW 1-1/8″	5305-01-004-4983
10-24 NYLON SCREW	5305-00-240-0259
FORMULA 80 VARNISH (TT-V-119) 1 QUART	8010-00-234-5176
CEMENT MMM-A-121 1/2 PINT	8040-00-273-8716
1 PINT	8040-00-273-8717
1 QUART	8040-00-165-8614
1 GALLON	8040-00-843-3461
CPR SIGN	0177-LF-008-1700
WARNING SIGN	0177-LF-008-1200
WORKBENCH CABINET ASSEMBLY	7195-00-851-2156
WORKBENCH CABINET BASE ASSEMBLY	7195-00-851-2157
WORKBENCH BACK PANEL AND SHELF	7195-00-851-2158
WORKBENCH AUXILIARY TABLE ASSEMBLY	7195-00-851-2159

Table 300-H-1 (PART 2) SELECTED WORKBENCH PARTS AND COMPONENTS

DRAWINGS	
NAVAIR 63A114JI	WORKBENCH ASSEMBLY
NAVAIR 63A114J2	CABINET ASSEMBLY
NAVAIR 63A114D3	BASE ASSEMBLY
NAVAIR 63A114D4	BACK PANEL AND SHELF
NAVAIR 63A114D5	AUXILIARY TABLE ASSEMBLY
NAVAIR 63A114D6	DRAWER ASSEMBLY
NAVAIR 63A114D7	CABINET STRUCTURE ASSEMBLY
NAVAIR 63A114D8	WORK SURFACE DETAIL
NAVAIR 63A114C9	DRAWER SLIDE
NAVAIR 63A114C10	TRAY INSERT FOR DRAWER
NAVAIR 63A114C11	TOP SHELF
NAVAIR 63A114C12	DISTRIBUTION BOX
NAVAIR 63A114C13	BACK PANEL ASSEMBLY
NAVAIR 63A114C14	ASSEMBLY INSTRUCTIONS
NAEC 6SE00063	WORKBENCH DECK SUPPORT AND GROUND INSTALLATION
NAVSEA 613-605897	SUPPORT, INSULATION & GROUNDING FOR 2FT ELECTRONIC WORKBENCHES (63A114)

APPENDIX I.

GENERAL PURPOSE TEST SWITCHBOARD (PANEL)

300-I.1 INTRODUCTION

300-I.1.1 GENERAL. Electrical test switchboards, Symbol 2457, drawing number 815-1853036, are used to energize and test electrical equipment. They are used individually, in electrical repair workshops and other work areas that require test power and measuring instruments.

300-I.1.2 ELECTRICAL POWER DISCONNECT SWITCHES. Personnel safety is of primary concern when using the test switchboards during maintenance on energized equipment. Power disconnect switches shall be provided to quickly disconnect workbench power (60Hz, 400Hz, DC). The disconnect switch(es) shall not be located on the test switchboard.

a. PREFERRED METHOD. A power disconnect switch (pushbutton station) shall be located just inside the access to the space. The switch shall disconnect ALL power (60Hz, 400Hz, DC) to the test switchboard. The pushbutton station (switch) shall be visible to personnel entering the space, readily accessible to safety observers and clearly identify which test switchboard(s) the pushbutton (switch) controls. The bulkhead mounted pushbutton station shall be located 48 to 54 inches above the deck, within a red-painted target. The pushbutton shall not be part of the normal protection devices for the test switchboard.
   (1) In large workshops, multiple disconnect pushbuttons (switches) shall be wired so activation of any pushbutton (switch) will secure ALL power (60Hz, 400Hz DC) to ALL test switchboards.

b. Power panels (60Hz, 400Hz, DC) installed in the same compartment as the test switchboards, may be used as test switchboard power disconnects. The circuit breaker(s) inside the power panel(s) shall be clearly marked with a red target around them for easy identification. They shall be clearly marked as to which test switchboards they control. If the power panel is in an adjacent compartment or is not readily accessible to the individual at the test switchboard, or a second party, a power disconnect switch (pushbutton station) shall be located just inside the access to the space (see paragraph 300-I.1.2a above).

300-I.1.3 TEST SWITCHBOARDS AND WORKBENCHES. Power for electrical test switchboards and electrical/electronic workbenches in the same compartment shall be controlled by the same power disconnect switch(es).

300-I.2 SIGNS AND LABEL PLATES.

a. Near the test switchboard post the following signs giving the approved method of rescuing personnel in contact with energized circuits.

b. and

DANGER
DO NOT ATTEMPT TO ADMINISTER FIRST AID OR COME INTO PHYSICAL CONTACT WITH AN ELECTRIC SHOCK VICTIM BEFORE THE POWER IS SHUT OFF

DANGER
REMOVAL OF PERSONNEL IN CONTACT WITH ENERGIZED ELECTRICAL CIRCUITS

DO NOT TRY TO REMOVE VICTIM WITH YOUR BARE HANDS

1. DE-ENERGIZE THE CIRCUIT IF POSSIBLE

2. IF CIRCUIT CANNOT BE DE-ENERGIZED:

– YOU MUST INSULATE YOURSELF FROM HIS ENTIRE BODY BY USING A NON-CONDUCTOR TO PUSH HIM FREE ON THE CONTACT

– IF YOU ARE IN CONTACT WITH A LIVE CIRCUIT AND NO ONE IS NEARBY TO HELP, TRY TO BREAK THE CONTACT BY THROWING YOUR BODY.

b. Adjacent to the test switchboard post Cardiopulmonary Resuscitation Placard NSN-0177-LF-008-1700 and the WARNING sign NSN-0177-LF-008-1200.

c. Post this label plate near the emergency cut-off switch(es).

e.

FOR EMERGENCY USE ONLY

TEST SWITCHBOARD
DISCONNECT SWITCH

Figure e.

REAR SECTION

NOTE

TECHNICAL MANUAL DEFICIENCY/EVALUATION EVALUATION REPORT (TMDER) Forms can be found at the bottom of the CD list of books. Click on the TMDER form to display the form.